Calhoun
Institutional Archive of the Naval Postgraduate School

**Calhoun: The NPS Institutional Archive**

**DSpace Repository**

Theses and Dissertations 1. Thesis and Dissertation Collection, all items

1977

# Design study of a centerplate mount for wind tunnel models.

Russell, Robert Wayne

http://hdl.handle.net/10945/18073

*Downloaded from NPS Archive: Calhoun*

DUDLEY
KNOX
LIBRARY

Calhoun is the Naval Postgraduate School's public access digital repository for research materials and institutional publications created by the NPS community. Calhoun is named for Professor of Mathematics Guy K. Calhoun, NPS's first appointed -- and published -- scholarly author.

Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943

http://www.nps.edu/library

# DESIGN STUDY OF A CENTERPLATE MOUNT FOR WIND TUNNEL MODELS

Robert Wayne Russell

LEY KNOX LIBRARY
AL POSTGRADUATE SCHOOL

# NAVAL POSTGRADUATE SCHOOL

Monterey, California

# THESIS

## Design Study of a Centerplate Mount for Wind Tunnel Models

by

Robert Wayne Russell

June 1977

Thesis Advisor: L. V. Schmidt

Approved for public release; distribution unlimited.

T180076

## REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS
BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (*and Subtitle*)
Design Study of a Centerplate Mount for Wind Tunnel Models

5. TYPE OF REPORT & PERIOD COVERED
Master's Thesis
June 1977

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(*s*)
Robert Wayne Russell

8. CONTRACT OR GRANT NUMBER(*s*)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, CA 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Postgraduate School
Monterey, CA 93940

12. REPORT DATE
June 1977

13. NUMBER OF PAGES
113

14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*)
Naval Postgraduate School
Monterey, CA 93940

15. SECURITY CLASS. (*of this report*)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)
Approved for public release distribution unlimited.

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)
Wind tunnel mounting system
Aerodynamic tare evaluation

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

A three-strut wind-tunnel model support system was being used with an electrical balance in the 3.5 by 5.0 foot Department of Aeronautics low-speed wind tunnel. The traditional method of image systems and alternate inverted mounting for the evaluation of aerodynamic tares was considered impractical for implementation in the small sized tunnel. The design and

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

20. ABSTRACT (continued)

installation of an alternate model support system using a centerplate mount was accomplished. An aerodynamic evaluation for comparing the two model mounting concepts was performed via experiments with a single calibration wing. Additionally, these experiments were the first operational exercise of a recently developed microprocessor data acquisition system.

Approved for public release; distribution unlimited.

# Design Study of a Centerplate Mount for Wind Tunnel Models

by

Robert Wayne Russell
Lieutenant, United States Navy
B.S.A.E., Purdue University, 1971

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
June 1977

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL

## ABSTRACT

A three-strut wind-tunnel model support system was being used with an electrical balance in the 3.5 by 5.0 foot Department of Aeronautics low-speed wind tunnel. The traditional method of image systems and alternate inverted mounting for the evaluation of aerodynamic tares was considered impractical for implementation in the small sized tunnel. The design and installation of an alternate model support system using a centerplate mount was accomplished. An aerodynamic evaluation for comparing the two model mounting concepts was performed via experiments with a single calibration wing. Additionally, these experiments were the first operational exercise of a recently developed micro-processor data acquisition system.

TABLE OF CONTENTS

I. INTRODUCTION ---------------------------------------- 12
II. MOUNT DESIGN CONSIDERATIONS ------------------------- 14
A. THREE-STRUT MOUNT PROBLEM AREAS --------------- 14
B. MODIFIED TASK MK I BALANCE LIMITATIONS -------- 16
C. TEST SECTION LIMITATIONS ON MODEL SIZE -------- 20
D. ALTERNATIVE MOUNT PROPOSALS ------------------- 22
III. MOUNT DESIGN ---------------------------------------- 24
A. TRADE-OFFS OF THE SELECTED CONFIGURATION ------ 24
B. MOUNT CONSTRUCTION FEATURES ------------------- 27
C. TUNNEL INTEGRATION ---------------------------- 29
IV. PROOF OF CONCEPT EXPERIMENT ------------------------- 33
A. PRELIMINARY PREPARATION ----------------------- 33
B. DESCRIPTION OF CALIBRATION WING --------------- 34
C. THREE-STRUT MOUNTING SYSTEM EXPERIMENTS ------- 35
D. ADAPTATION OF CALIBRATION WING ---------------- 36
E. CENTERPLATE MOUNTING SYSTEM EXPERIMENTS ------- 39
F. THEORETICALLY EXPECTED RESULTS ---------------- 39
V. PRESENTATION OF DATA -------------------------------- 43
VI. CONCLUSIONS ----------------------------------------- 62
A. DATA ANALYSIS --------------------------------- 62
B. RECOMMENDATIONS ------------------------------- 65
APPENDIX A ----------------------------------------------- 67
APPENDIX B ----------------------------------------------- 69
APPENDIX C ----------------------------------------------- 73

COMPUTER PROGRAMS------------------------------------------ 111
REFERENCES ------------------------------------------------- 112
INITIAL DISTRIBUTION LIST ---------------------------------- 113

# LIST OF TABLES

| TABLE | CONTENT | MOUNT | Q(psf) | PAGE |
|---|---|---|---|---|
| I. | Run Log | | | 45 |
| II. | Corrected Data, Run 051501 | Three-strut | 40 | 49 |
| III. | Corrected Data, Run 051801 | Three-strut | 40 | 50 |
| IV. | Corrected Data, Run 051802 | Three-strut | 30 | 51 |
| V. | Corrected Data, Run 051803 | Three-strut | 20 | 52 |
| VI. | Corrected Data, Run 052703 | Centerplate | 40 | 56 |
| VII. | Aerodynamic Tares of Run 052703 | | 40 | 57 |
| VIII. | Corrected Data, Run 052702 | Centerplate | 30 | 58 |
| IX. | Aerodynamic Tares of Run 052702 | | 30 | 59 |
| X. | Corrected Data, Run 052701 | Centerplate | 20 | 60 |
| XI. | Aerodynamic Tares of Run 052701 | | 20 | 61 |
| XII. | Raw Data, Run 051501 | Three-strut | 40 | 75 |
| XIII. | File Listing, Run 051501 | | | 76 |
| XIV. | Raw Data, Weight Tare 051577 | Three-strut | 0 | 77 |
| XV. | File Listing, Run 051577 | | | 78 |
| XVI. | Raw Data, Run 051801 | Three-strut | 40 | 79 |
| XVII. | File Listing, Run 051801 | | | 80 |
| XVIII. | Raw Data, Run 051802 | Three-strut | 30 | 81 |
| XIX. | File Listing, Run 051802 | | | 82 |
| XX. | Raw Data, Run 051803 | Three-strut | 20 | 83 |
| XXI. | File Listing, Run 051803 | | | 84 |
| XXII. | Raw Data, Weight Tare 051877 | Three-strut | 0 | 85 |

| TABLE | CONTENT | MOUNT | Q(psf) | PAGE |
|---|---|---|---|---|
| XXIII. | File Listing, Run 051877 | | 40 | 86 |
| XXIV. | Raw Data, Aero Tare Wing-Off Run 052602 | Centerplate | | 87 |
| XXV. | File Listing, Run 052602 | | | 88 |
| XXVI. | Raw Data, Aero Tare Wing-Off Run 052603 | Centerplate | 30 | 89 |
| XXVII. | File Listing, Run 052603 | | | 90 |
| XXVIII. | Raw Data, Aero Tare Wing-Off Run 052601 | Centerplate | 20 | 91 |
| XXIX. | File Listing, Run 052601 | | | 92 |
| XXX. | Raw Data, Weight Tare Wing-Off, Run 052677 | Centerplate | 0 | 93 |
| XXXI. | File Listing, Run 052677 | | | 94 |
| XXXII. | Raw Data, Wing-On, Run 052703 | Centerplate | 40 | 95 |
| XXXIII. | File Listing, Run 052703 | | | 96 |
| XXXIV. | Raw Data, Wing-On, Run 052702 | Centerplate | 30 | 97 |
| XXXV. | File Listing, Run 052702 | | | 98 |
| XXXVI. | Raw Data, Wing-On, Run 052701 | Centerplate | 20 | 99 |
| XXXVII. | File Listing, Run 052701 | | | 100 |
| XXXVIII. | Raw Data, Weight Tare, Run 052777 | Centerplate | 0 | 101 |
| XXXIX. | File Listing, Run 052777 | | | 102 |

# LIST OF FIGURES

1. Three-strut mount and calibration wing ------------ 15
2. Wing attach point detail -------------------------- 15
3. Left side, modified Task MK I balance ------------- 17
4. Right side, modified Task MK I balance ------------ 17
5. Balance parallelogram geometry -------------------- 19
6. View of 3.5 x 5.0 test section -------------------- 21
7. View of sizing trade-offs ------------------------- 25
8. View of centerplate installation ------------------ 30
9. Q calibration testing ----------------------------- 30
10. Q calibration curves ------------------------------ 32
11. Centerplate and bullet fairing, wing-off ---------- 38
12. Centerplate and bullet fairing, wing-on ----------- 38
13. Lift curve, three-strut mount --------------------- 46
14. Drag polar, three-strut mount --------------------- 47
15. Pitching moment curve, three-strut mount ---------- 48
16. Lift curve, centerplate mount --------------------- 53
17. Drag polar, centerplate mount --------------------- 54
18. Pitching moment curve, centerplate mount ---------- 55
19. Three-strut moment transfer relations ------------- 71
20. Centerplate moment transfer relations ------------- 72

# TABLE OF SYMBOLS

## Latin Symbols

| | |
|---|---|
| A.C. | Aerodynamic center |
| $c$ | Wing chord ft |
| $\bar{c}$ | Mean aerodynamic chord (MAC), ft |
| ℄ | Centerline |
| $C_D$ | Non-dimensional drag force coefficient = D/QS |
| $C_L$ | Non-dimensional lift force coefficient = L/QS |
| $C_M$ | Non-dimensional pitch moment coefficient = M/QSc |
| D | Drag force, lbs, positive in aft direction |
| L | Lift force, lbs, positive in up direction |
| M | Pitching moment, ft-lbs, positive in nose up direction |
| Q | Dynamic pressure, lbs/ft$^2$ (PSF), = $\frac{1}{2} \rho V^2$ |
| $R_N$ | Reynolds number, non-dimensional, for the wing = $\rho Vc/\mu$ |
| S | Wing area, ft$^2$ |
| V | Velocity, ft/sec, positive in downstream direction |

## Greek Symbols

| | |
|---|---|
| $\alpha$ | Angle of attack (AOA), deg. or rad., positive in nose up direction |
| $\Delta$ | Change in position or specified variable, $\Delta(\ )$ |
| $\rho$ | Density, slugs/ft$^3$ |
| $\mu$ | Absolute viscosity, slugs/ft-sec |
| $\nu$ | Kinematic viscosity, ft$^2$/sec = $\mu/\rho$ |

## Subscripts

| | |
|---|---|
| $(\ )_{\bar{c}/4}$ | Variable referenced to 0.25 MAC |
| $(\ )_o$ | Variable evaluated at $C_L = 0$ |

# ACKNOWLEDGMENT

The sincere gratitude of the author goes to Professor Louis V. Schmidt for his patience, knowledge and professional example. Additional thanks go to technicians Glenn Middleton, Ron Ramaker and Stan Johnson for their help, interest and craftsmanship in the project.

# I. INTRODUCTION

The Department of Aeronautics at the Naval Postgraduate School (NPS) has seen limited low-speed wind-tunnel work in either its curricula or student research over the past several years despite housing several fine low-speed tunnels. The tunnel of primary interest was built to NPS specifications and design by West Coast Research. It offers an octagonal test section with 3.5 by 5.0 foot measurements and a maximum tunnel operating dynamic pressure (Q) of approximately 100 psf from its two-stage fan section. Although it is an excellent small tunnel, several factors have limited its use;

(1) Lack of modern, electronic balance capable of supplying analog voltage signals,

(2) Lack of a data acquisition system to convert analog voltage into convenient digital form,

(3) Lack of a potential computer program for the calculation of wall correction factors for an arbitrary wing configuration, and

(4) Lack of a flexible mounting system that would ease model construction, allow rapid model or configuration changes, and enable measurement of aerodynamic tares.

Recently, an improvement program has been initiated to correct the limiting factors with the objective of producing an integrated tunnel system. Work documented by Concannon in

Ref. 1 has removed factor one. Current work by Casko, Ref. 2, and Heard, Ref. 3, is projected to remove factors two and three, respectively. This thesis is a design study for a solution to factor four, namely, the development of an improved model mounting system. It is important to note the balance system lends itself to three-component longitudinal airframe data, only. Downstream planning is needed to acquire a full six-component balance facility capable of yielding aerodynamic information at both angle of attack and sideslip.

Completion of the integrated system should provide a modern, highly automated tunnel system, readily adaptable to various demands and capable of generating accurate airframe data suitable for engineering analysis.

# II. MOUNT DESIGN CONSIDERATIONS

## A. THREE-STRUT MOUNT PROBLEM AREAS

The three-strut mount has traditionally found great favor in low-speed wind tunnels for testing conventionally configured, nonaeroelastic models. As seen in figure 1, the three-strut mount consists of two main struts supporting the wing at two wing station attachment points, and a third strut attached to an aft tail sting. This type of mount is sufficiently rigid and offers ease of angle of attack variation, as pointed out on pg. 149 in Ref. 4. For larger low-speed tunnels, drag tare and interference evaluation is possible; however, the three-strut model support system is quite complex in this regard. Small tunnel size compounds the problem and most academic tunnels forego the evaluation of aerodynamic tares.

Exposed struts contribute a drag tare and/or a pitching moment variation in the case of the aft strut. Partial compensation is possible through the use of strut fairings or windshields over some of the exposed struts. Strut to fairing interference, though present, is usually negligible in small tunnels. A more serious interference effect is that of the wing strut and fairing on the wing, inducing unknown flow disturbances onto the wing's flow field.

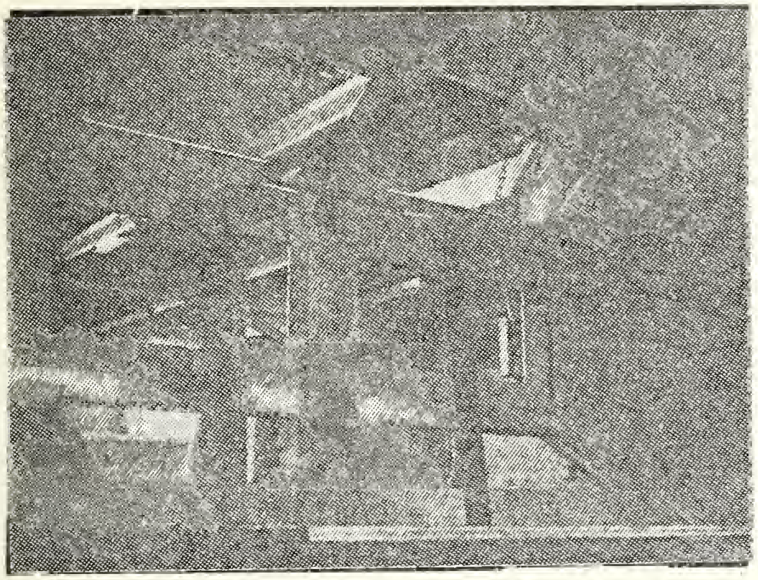
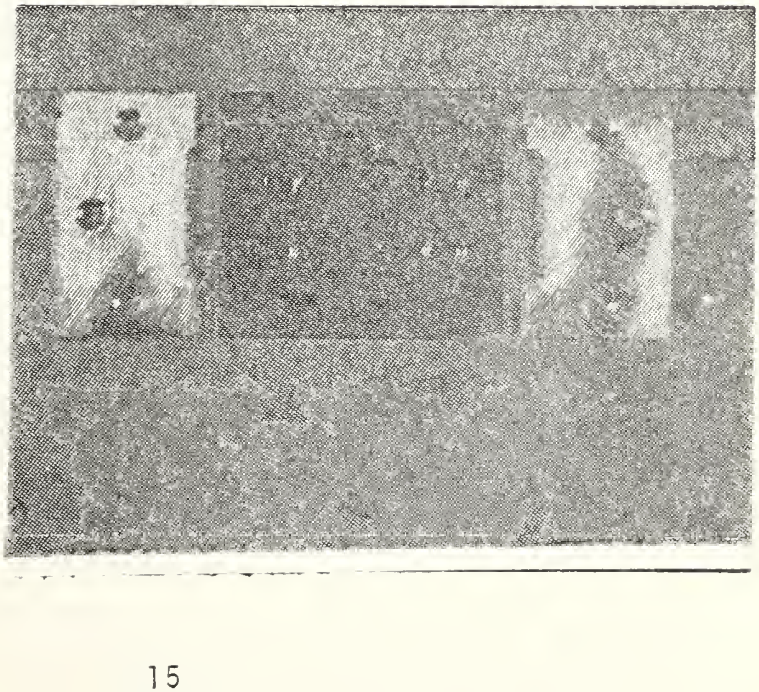


Figure 1. Three-strut mount and calibration wing.

Figure 2. Wing attach point detail.



Techniques for the evaluation of this effect are documented in the literature and utilize a procedure involving an image system and alternate inverted mounting; cf, pp. 175-180, Ref. 4. Figure 2 depicts the requirement for extremely fine image detail and model hardware to facilitate this scheme. The investment in time and detail is usually by-passed in small tunnels because of the small absolute size of the correction sought and the inherent resolution of the balance system employed. The third strut varies the angle of attack, and it is reasonable to assume that an unfaired strut will contribute drag and pitching moment tares as a function of angle of attack. Elaborate, variable fairings have been devised to keep the exposed portion of the aft strut constant in some large tunnels, but aft struts are generally unfaired in small tunnels. Additionally, wing attachment points preclude model experiments for investigating aeroelastic effects. A mounting system which would relax the above restrictions within the limitations of the tunnel balance and test section area was required.

## B. MODIFIED TASK MK I BALANCE LIMITATIONS

The Department of Aeronautics acquired a Task Corporation MK I balance in 1958. The balance was a standard, three-component beam balance capable of lift, drag and pitching moment measurements. In Ref. 1 Concannon describes modifications made to the balance to provide electrical strain gage

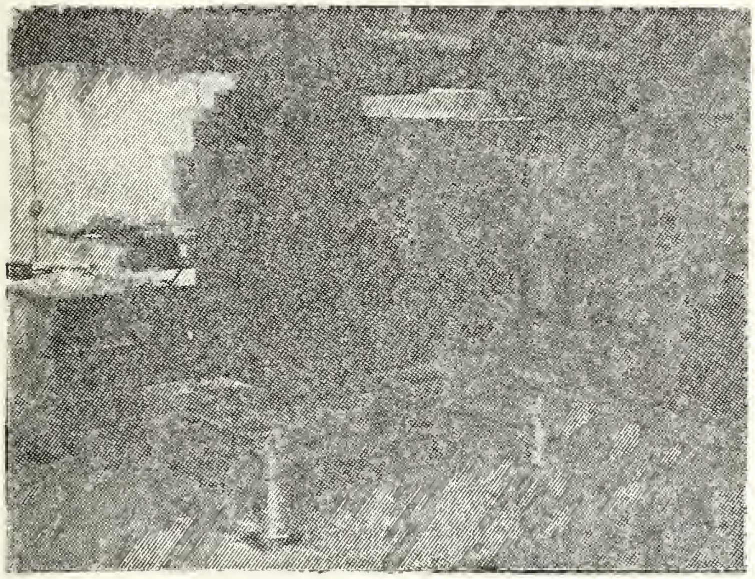


Figure 3. Left side modified Task MK I balance.

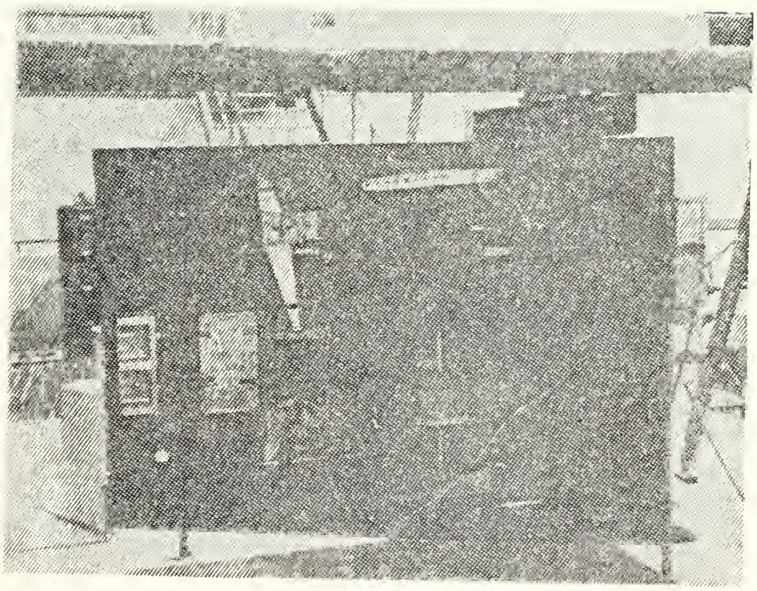


Figure 4. Right side, modified Task MK I balance.

outputs, thereby upgrading its potential as an element of a modern data acquisition system. Figures 3 and 4 show the Task balance in its modified configuration.

Adoption of strain gage measurement imposes linear response load ranges. Concannon selected these ranges as;

± 500 lbs. in lift,
± 75 lbs. in drag, and
± 75 ft.-lbs. in pitching moment

These values were taken as the expected maximum working loads for the proposed mount.

Figure 4 depicts the large cross beam for main strut support and a small aft lever arm for varying angle of attack via a tail strut. As would be supposed, the balance was designed for a three-strut mount shown previously in figure 1. The provisions for main beam support and aft angle of attack drive had to be incorporated in the proposed design.

The balance is also configured so that the geometry of a parallelogram had to be established and maintained for constant one-to-one angle of attack tracking. Figure 5 depicts the relationship between the lever arm pivot, main trunnion and aft pins. This was a primary consideration for the design of an alternate mount.

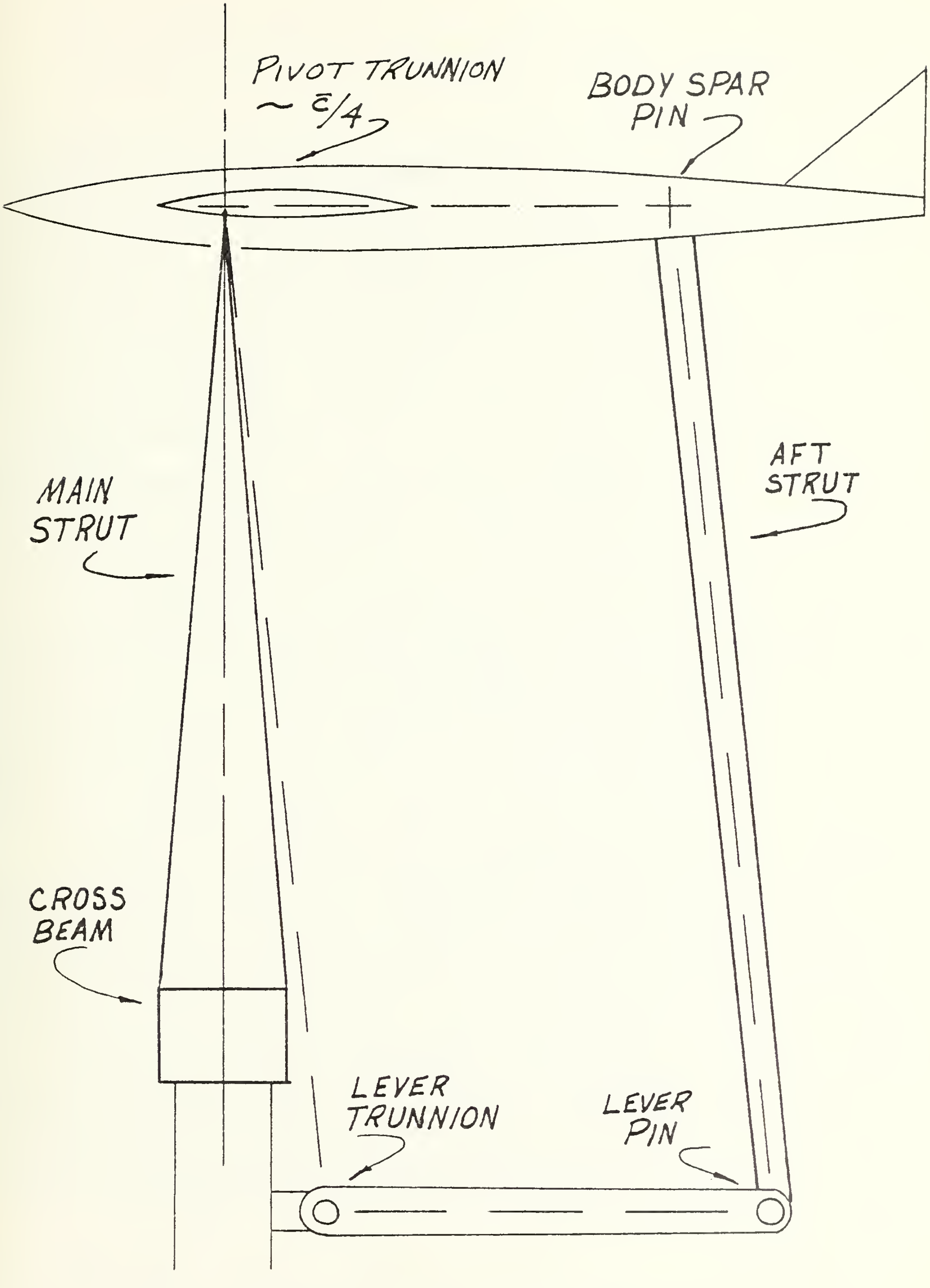


Figure 5. Balance parallelogram geometry.

## C. TEST SECTION LIMITATIONS ON MODEL SIZE

The primary NPS low-speed tunnel offers a 3.5 by 5.0 foot test section with 20-inch fillets forming an octagonal cross-section as seen in figure 6. The main limitations imposed by test section size are the model span and a trade-off between tail/canard moment arm and geometric angle of attack. The general rule of thumb for span is that it should be no more than 80% of the test section width. This yields a maximum span of four feet with six-inch tip clearance. Maximum moment arm is a function of maximum angle of attack and the allowable proximity of the tail or canard to a tunnel wall. A minimum six-inch clearance for the tail A.C. at maximum angle of attack was assumed for design purposes. The reason for the clearance requirement is the breakdown of potentially derived or empirically estimated wall corrections in the turbulent boundary layer.

A span of four feet and an aspect ratio of six yields a chord of 0.677 feet for a straight untapered wing. At standard sea level conditions and a Q of 60 psf, a Reynolds number of 950,000 resulted. Maximum tunnel Q, 100 psf, would only increase the Reynolds number to 1,250,000. These Reynolds number values are low for testing in the turbulent regime without some form of boundary layer tripping. Small aspect ratios and larger chords for the four-foot span would improve the situation, but low Reynolds numbers still represent a penalty inherent in small tunnels. For this reason tunnels

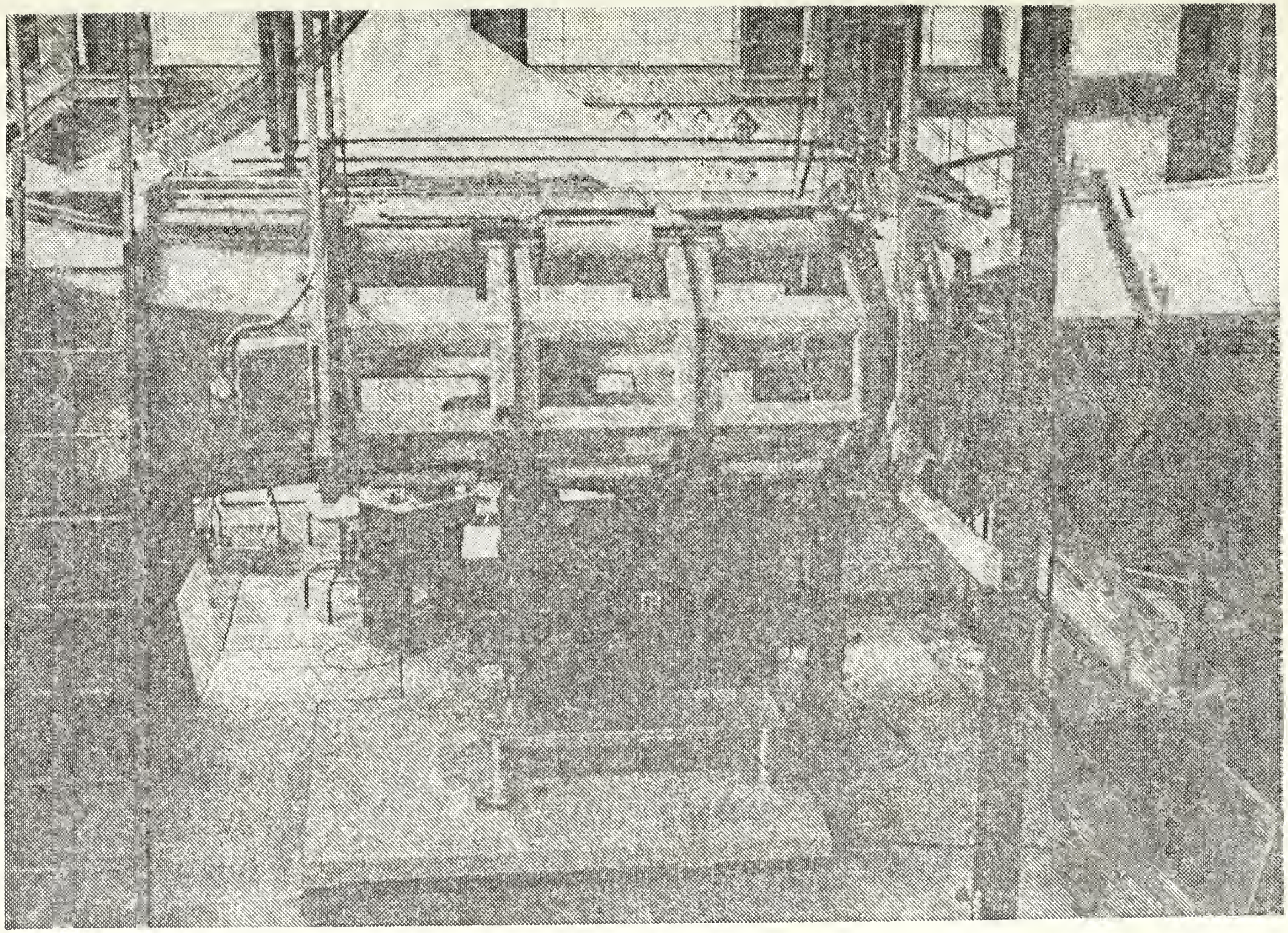


Figure 6. View of 3.5 x 5.0 test section.

of the 3.5 by 5.0 foot size represent those used primarily for academic purposes or for work where Reynolds number scaling is of lesser importance.

Test section size also affects the amount of deviation from the centerline that is negligible, and the allowable solid blockage by the mount. Of course, it is best to keep both to a minimum, but they are generally not driving concerns, providing tunnel flow calibrations are accurate and the velocity profile is well developed and uniform.

## D. ALTERNATE MOUNT PROPOSALS

Several mount configurations were proposed as solutions to the problem outlined in part A and the compatibility constraints listed in parts B and C. Balance limitation to three-component measurements considerably eased the problem of achieving sufficient lateral-directional rigidity. Minimum mount complexity and interference with the primary aerodynamic surfaces was sought. These goals indicated a reduction in the number of struts, removal of the attach points from the wing and a design that could be adapted to the measurement of aerodynamic tares. Candidate proposals then included the single strut, tandem struts, centerplate and tail sting mounts.

The single strut mount is the simplest and keeps interference to a minimum but is weak in torsion and concentrates the stresses at a single attach point under the fuselage of

a model. A fairly large strut width is required to provide sufficient rigidity and reasonable stress levels at design loads.

The tandem strut arrangement appeared to add no benefits at the cost of added complexity, but again, interference would be near minimum.

The centerplate mount represented what could be considered a continuous compromise of the previous two mount proposals. It would require only a single fairing, and the plate could fit in a slot along the under side of a model's fuselage. It seemed apparent that this mount would distribute the attachment forces more evenly, and that the detail of single point attachment would be eliminated. Width was traded for length, and the question of interference increase remained to be answered.

Tail sting mounting was the final consideration. Although it offered the least interference and nil blockage, the mount is optimized for single jet models in a high-speed tunnel. Limited angle of attack variation was another constraint of this type. A more complex adaptation for angle of attack drive would also be required.

Centerplate mounting appeared the most promising, and it was felt that the questioned increase in interference over the single strut mount would be negligible, if any. This approach was selected, and further design considerations are addressed in subsequent sections.

# III. MOUNT DESIGN

## A. CENTERPLATE CONFIGURATION TRADE-OFFS

After selection of the centerplate as the most promising design, several immediate engineering decisions were required to fix mount geometry. Since the mount would be expected to test a wide variety of models and wing types, a -15° to plus +30° angle of attack range was arbitrarily selected. The location of the plate trunnion about which the plate would describe a circular arc was a primary consideration. Selection of the arc radius with the plate at zero angle of attack fixes the trunnion location vertically below the test section centerline. Further considerations on this radius length were the tail-to-wall proximity at maximum angle of attack for a representative tail moment arm, 25 inches assumed, and the amount of fairing blockage required to shield the main support. Minimum radius length improves the former but is inverse for the latter. As stated previously, a minimum wall clearance of six inches for all aerodynamic surfaces was desired. A small radius also favors minimum deviation from test section centerline, but then incurs the possibility of interference by the proximity of the fairing. The trade-off considerations are depicted in figure 7.

Rough plots of various parameters as a function of arc radius were constructed and an engineering judgment on a 14-inch radius was made.

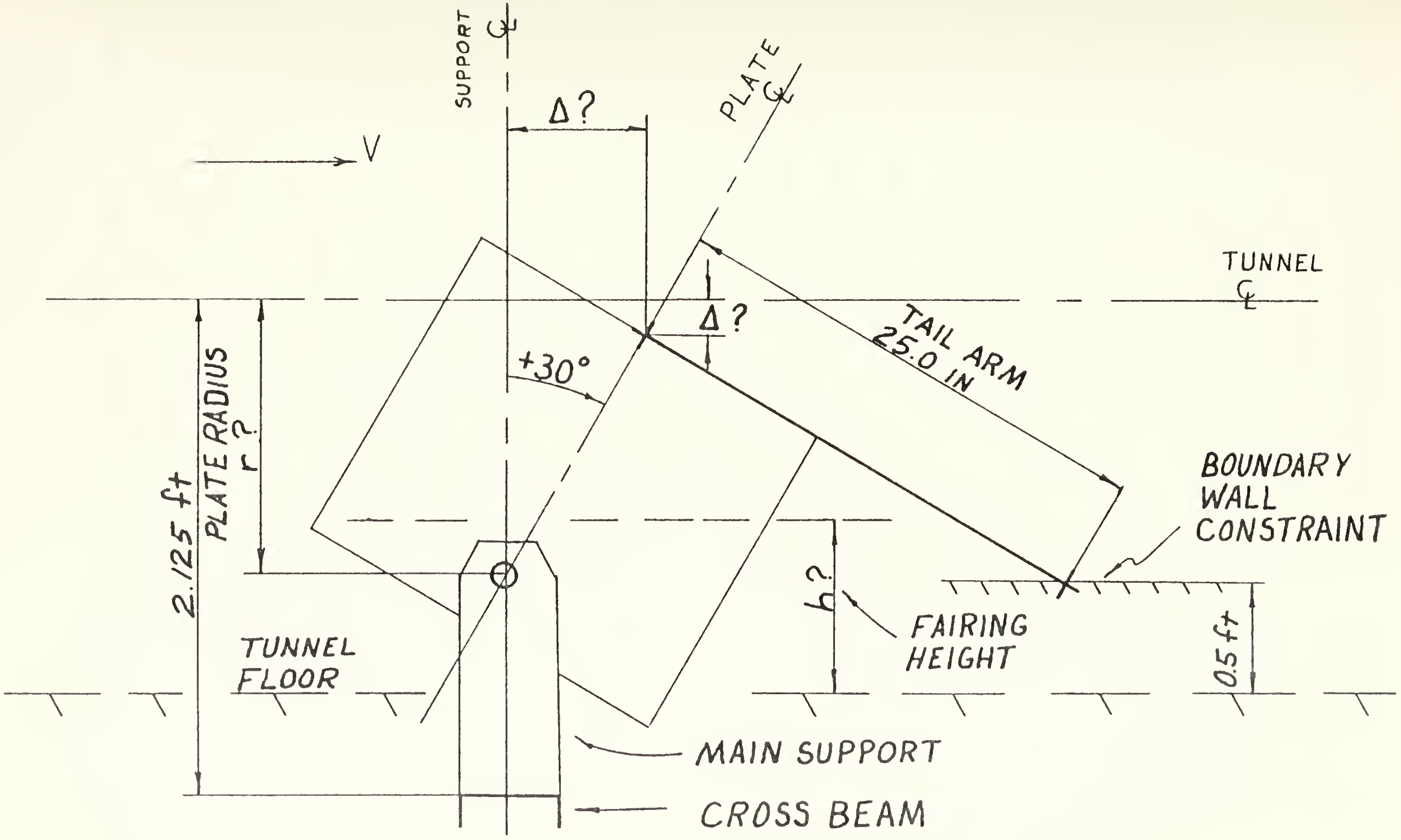


Figure 7. View of Sizing Tradeoffs.

The basic mount geometry was thus fixed. For an A.C. on the test section centerline and balance focal point when $\alpha = 0°$, its vertical deviation is -0.48 inches and the longitudinal deviation is ± 3.62 inches for $\alpha = \pm 15°$. The maximum vertical deviation is -1.88 inches and the maximum longitudinal deviations are +3.62 inches forward/-7.00 inches aft respectively for the design condition $\alpha = -15°, +30°$. Vertical deviation in the ±15° case is 1.1% of tunnel height vs. 4.5% for the maximum +30° condition. It should be noted that the vertical displacement represents the only increase of tail/canard proximity compared to a three-strut mount pivoting about an axis through the centerline. These were considered acceptable for well developed, tunnel flow profiles. By mounting the wing above the plate's upper surface, maximum deviation of the A.C. can be reduced since the total variation could be made to center about the test section centerline in addition to the option of providing a desired design model angle condition on the test section centerline.

Plate length was selected as twenty inches, ten inches on each side of the vertical centerline when the plate is at $\alpha = 0°$. This represented a trade-off between model fuselage slot length, fairing length and lateral-directional rigidity. A fuselage spar was predicted to give added directional rigidity, and so a sizeable 20-inch width was selected to improve its torsional bending resistance for a given thickness.

## B. MOUNT CONSTRUCTION FEATURES

Having fixed centerplate geometry, the detailed design work remained. Simplicity, strength and rigidity were the primary design goals. A design safety factor of ten over yield for the most critical combination of maximum working loads outlined in section II, part B, indicates the emphasis on eliminating structural deformations.

A single stainless steel support with a vertical fork to accept the centerplate was adopted. A one-half inch diameter steel trunnion pin installed with an interference fit to the aluminum centerplate was supported in journal bearings of the flanking doublers. Plate thickness was selected as three-eighths inch, with twin three-sixteenth inch doublers below the level of the fairing.

The left fork of the main support was designed to be removable for initial installation of the centerplate assembly and for later adaptation or modification as desired. The plate was attached with four 1/4 - 20 cap screws and trued by two alignment pins.

The main support was directly attached to the Task balance by 1/4 - 20 cap screws and a backing plate. The bottom of the support was submerged five inches below the level of the tunnel floor. The remainder of the support and lower third of the centerplate incorporated a fairing for smooth flow and minimal interference.

The fairing consists of wooden, contoured leading and trailing edges, an angle frame of aluminum and two removable aluminum side plates. Close attention was paid to fairing aerodynamics to minimize cross flow separation at the leading edge and adverse pressure gradient separation at the trailing edge. A slot was milled into the upper cap to allow approximately one-sixteenth inch clearance for the centerplate. The entire fairing was to be mounted on a three-quarter inch plywood tunnel floor. The old flooring was retained to accommodate the original three-strut mount, if some unforeseen requirement for it should arise. The fairing was 12.5 inches high with a cross-section of 27.45 square inches. This represents a blockage factor of 1.31% for the tunnel test section. The resulting blockage appeared to be acceptable, and a tunnel Q calibration was performed with plate fairing installed.

The angle of attack was varied by a strut attached to the aft end of the centerplate and submerged under the fairing. An adjustable turnbuckle was incorporated to provide precise parallelogram alignment for proper angle of attack tracking.

The entire mount was fabricated to the specification of the author by the craftsmen of the Department of Aeronautics model shop from readily available materials. Critical part tolerance met or exceeded 0.002 inches.

## C. TUNNEL INTEGRATION

The original three-strut mount was removed after the collection of baseline data. The three-quarter inch plywood flooring was removed to keep the three-strut system intact. Then, the main support was checked on the main beam of the balance to insure correct fit. A new one-piece plywood floor was fabricated and mated to the test section framework. The fairing was then fastened along the test section centerline. The fairing sides were removed, and the centerplate was installed (see figure 8). The aft strut was adjusted, and the angle of attack was trued. The angle of attack was checked by a precision inclinometer throughout the design range of the mount, and found to be accurate within one second of arc. Concurrently, a check was made to ensure proper clearances of the plate, main support and aft strut. Rolling moments were applied to the plate to ensure minimal torsional deflection and to confirm that plate and fairing slot interference would not occur. An interference light was rigged with a series circuit between the balance and fairing. Subsequent runs indicated no fairing interference and that torsional rigidity was not a factor at the highest Q tested for a representative wing, 50 psf. Some minor alterations to the fairing framework were made to improve access to the main support side plate, but no major problems were encountered in the installation phase.

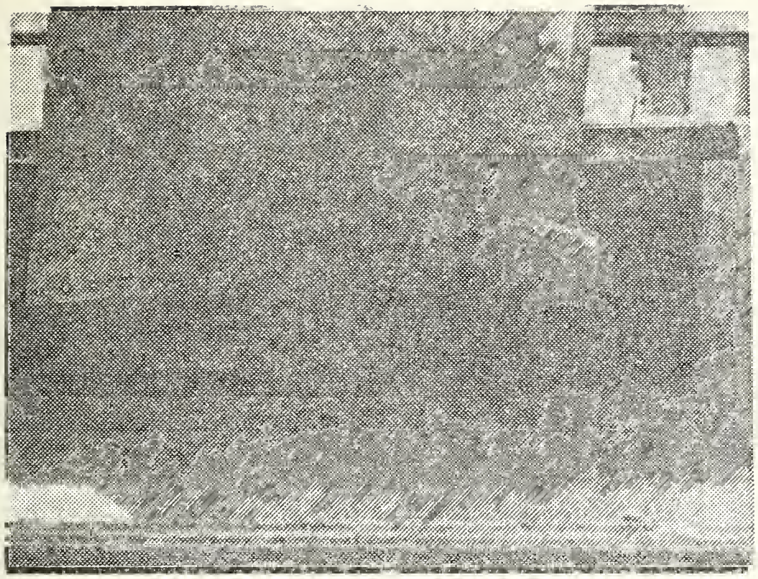
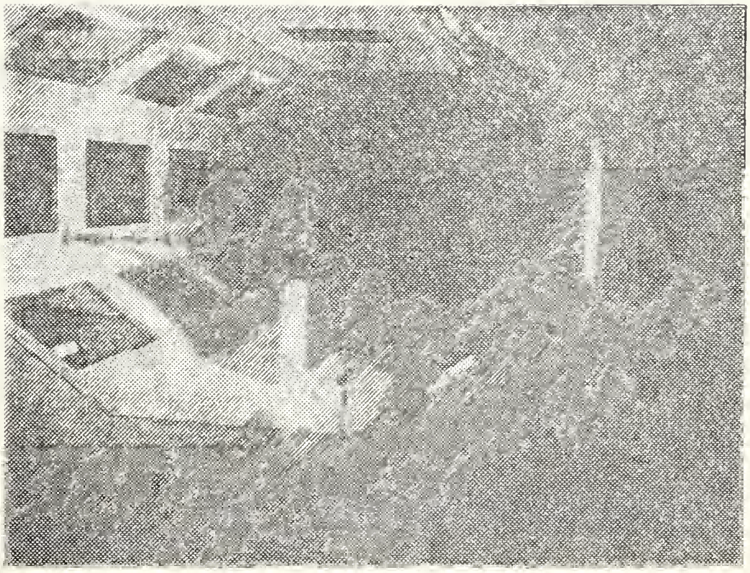


Figure 8. View of centerplate installation

Figure 9. Q calibration testing.



Once installed, a dynamic pressure calibration was performed to account for the revised tunnel configuration, including the centerplate fairing (see figure 9). The procedure was to take readings of a shrouded total pressure, a piezo ring static pressure, and a pitot-static tube which included total Q and static pressure measured over the fairing on the tunnel centerline. The first two pressure sources combine to yield a reference Q, $Q_{ref}$, while the last two pressures establish the Q to be calibrated, $Q_{cal}$.

Initially, an attempt to measure these values was made with a scanivalve; however, tunnel turbulence and the time delay of manual switching between data channels produced widely scattered data. At this point the power of the data acquisition system was utilized, and it was reprogrammed to scan each pressure transducer 128 times during a two-second time frame and numerically average the sample readings. The resulting scatter was noticeably reduced. Further refinement of the Q readings was made by incorporation of the subsonic pitot-static correction for compressibility effects [Ref. 5]. For Q's available to the low-speed tunnel, errors on the order of 1.0% could occur if the Mach correction were not taken into account. A summary of this Q correction is presented in figure 10.

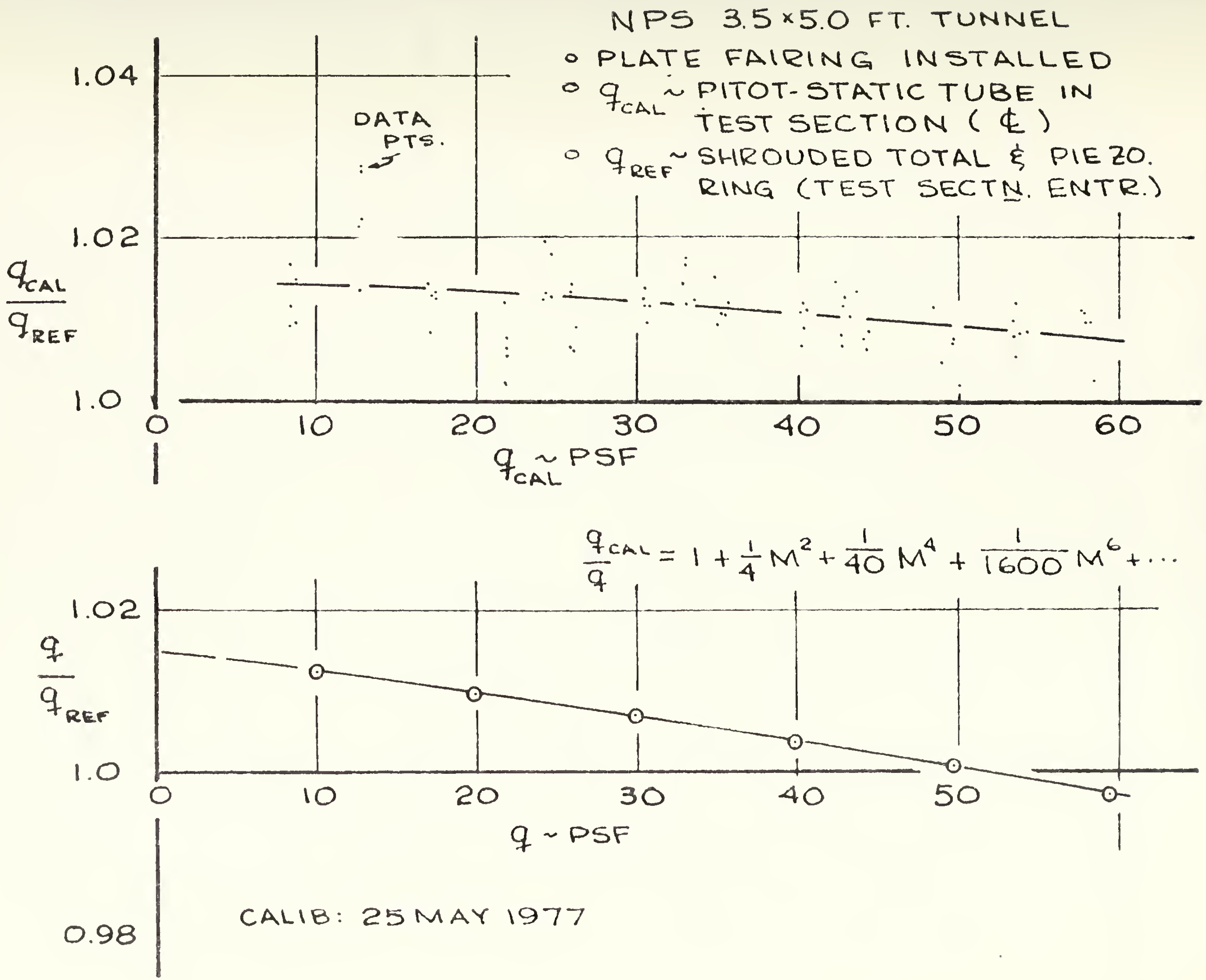


Figure 10. Q calibration curves.

## IV. PROOF OF CONCEPT EXPERIMENT

During the time period when the plate mount system was being fabricated, experiments were initiated to provide baseline data suitable for verification of the plate mount concept using an existing calibration wing. An added goal of the test sequence was the proof testing under actual laboratory conditions of the microprocessor oriented data acquisition system developed independently by Casko (Ref. 2). Initial testing, after modification of the Task MK I balance, indicated that inaccuracies were present due to the unavailability of the aerodynamic tares and the interference inherent when testing with a three-strut model support system. The accurately constructed calibration wing, which was available for the three-strut mount tests (see Figure 1), was subsequently adapted for comparable experiments upon the plate mounting system.

### A. PRELIMINARY PREPARATION

The signal conditioning amplifiers used by Concannon (Ref. 1) when acquiring his reported strain gage calibrations were rebuilt by the Department of Aeronautics for the express purpose of making possible improved electronic interfacing with the new data acquisition system. Therefore, a more current set of calibration matrix constants had to be determined. This was performed with a static loading frame and

calibration weights on the three-strut mounting system while installed in the tunnel test section. Following procedures outlined by Concannon in Ref. 1, the balance was calibrated to resolve lift force, drag force and pitching moment relative to a lateral axis through the intersection of the main strut trunnion axis and the vertical centerline of the balance cross beam. It is important to note that the accurate resolution of forces and moments about this axis (the virtual center or focal point of the balance) is independent of the type of support mount used, and any offset of a desired model reference point requires a moment transfer. Numerical values for the correlated reduction matrix constants may be found in Appendix A.

It should also be noted that the first stage fan blades were removed from the tunnel for refurbishing prior to the course of these experiments, which in turn effectively limited the tunnel test section operating dynamic pressure (Q) to approximately 55 pounds per square foot (psf). No advantage was seen in pushing the single stage fan to its limit, hence a dynamic pressure range of 20 to 40 psf was selected for test purposes.

## B. DESCRIPTION OF CALIBRATION WING

The calibration wing available for the experiment had a modified NACA 63-010 airfoil, constant over a three-foot span. The wing was without taper or twist, and had a six-inch chord. The rectangular wing tip sections were adapted

from NACA 63-015 contours. The wing attached to the main struts of the three-point mount at two wing trunnions located six inches on either side of the longitudinal axis, and coincident with the quarter-chord line. A thin steel sting attached to the wing spar and trailed aft to the tail strut pin attachment point. Sting width in the airfoil section was 0.50 inches, and it was filleted to 0.25 inches from the wing trailing edge to the aft tail strut clevis pin region. The sting moment arm for the three-strut mount was 15.00 inches.

## C. THREE-STRUT MOUNTING SYSTEM EXPERIMENTS

The objective of the three-strut mount experiments was to document accurately the performance of the calibration wing upon this type of support system without aerodynamic tare estimations being applied. The main struts were carefully faired by individual windshields to within approximately four inches of the wing surface. The aft (tail) strut was unfaired.

Wind-off weight tares for the aforementioned configuration were recorded through the angle of attack test range of -6.0 to +14.0 degrees by one degree increments. The tunnel Q was set to approximately 40 psf, and uncorrected aerodynamic data were recorded as printout on an ASR-33 Teletype unit. It should be noted that each printed row of information included five channels of data at a particular angle of

attack condition, including a numerically averaged Q value obtained during that two-second sampling period. This feature of the data acquisition system eliminated the necessity for precise tunnel dynamic pressure management.

After several days had transpired, the above data collection procedure was duplicated in its entirety to verify the repeatability of the system. Additional data for test runs at Q values of 20 and 30 psf were also collected. Each pitch-pause polar run required about eight minutes for approximately 30 individual angle of attack settings.

## D. ADAPTATION OF CALIBRATION WING

The calibration wing was originally designed for a three-strut support system. The wing attachment points had approximately two-inch square, contoured cover plates on both upper and lower surfaces (see figure 2). These were faired in with modeling clay and smoothed. The wing also had a one-half inch channel to accept the tail sting.

The forward section of the tail sting was duplicated to adapt the wing, but sufficient steel material was retained on the underside of the adaptor to allow the milling of a plate attachment slot. The centerplate was secured in this slot by two 1/4-20 cap screws. Two additional cap screws were inserted vertically through the adaptor and wing spar to fasten into tapped holes on the plate's upper surface. The wing adaptor was designed to position the wing quarter-chord

on the plate's vertical centerline, which aligned with the balance focal point at zero angle of attack. This feature was provided for geometrical simplifications in the moment transfer equations, as outlined in Appendix B.

A slender, bullet-shaped body fairing was incorporated to insure minimal flow disruption at the wing root. The fairing was constructed with two separate wooden center sections. One center section was solid (without wing cutouts) to provide a smooth fairing during wing-off weight and aerodynamic tare evaluations (see Figure 11). The other center section was contoured to accept the wing adaptor and wing panel (see Figure 12). Both fairings were fastened to either plate or wing adaptor by cap screws. Careful attention to tolerance details provided a close fit of the fairing to wing and plate and enhanced the torsional rigidity of the wing root, inasmuch as the actual wing spar details allowed only a one-half inch wide steel adaptor.

The fairing was kept as small as possible, and the two-inch fairing diameter represented 5.56 percent of the wing's three foot span. The small relative size of the body fairing provided an intuitive feeling that wing lift carry-over in the fairing area would be quite reasonable.

An approximate stress analysis was performed for wing root bending of the aluminum wing spar. A 40 percent margin over yield was estimated for design loads at Q = 60 psf. This seemed reasonable, since maximum test Q was selected as 40 psf.

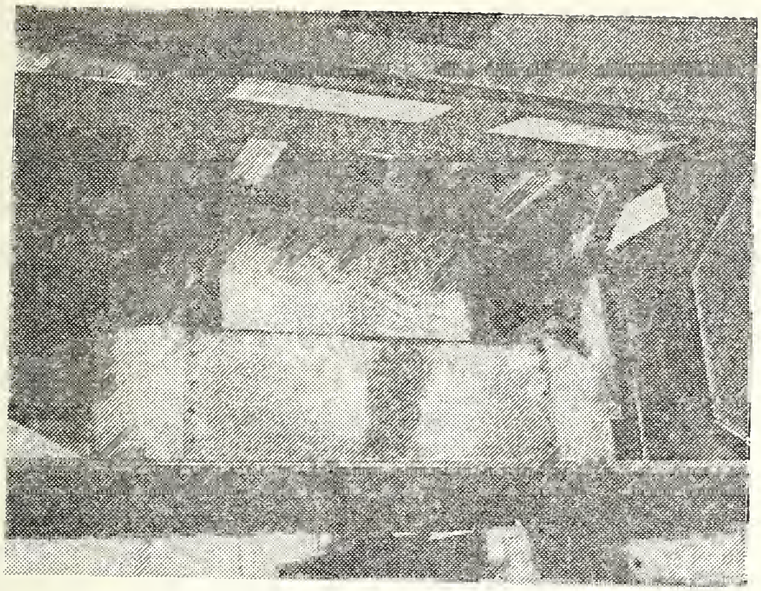
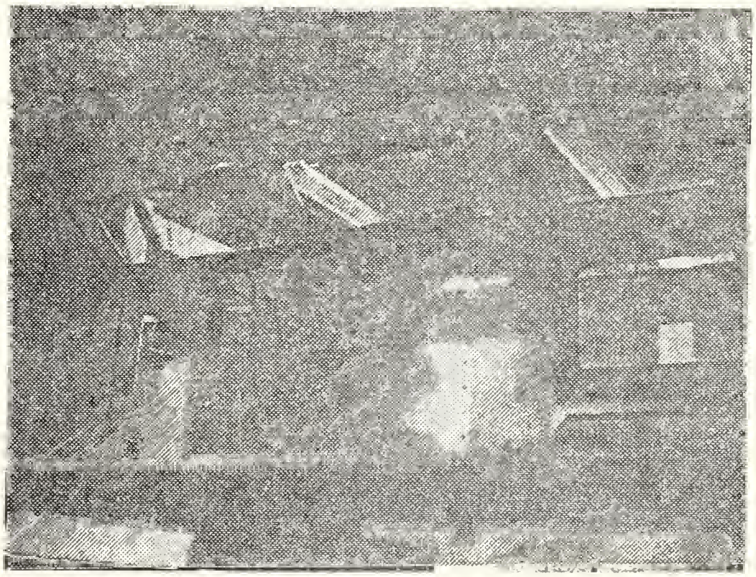


Figure 11. Centerplate and bullet fairing, wing-off.

Figure 12. Centerplate and bullet fairing, wing-on.



## E. CENTERPLATE MOUNTING SYSTEM EXPERIMENTS

The objective of the centerplate mount experiments was to document accurately the performance of the modified calibration wing when installed on the plate mount, including estimates of the aerodynamic tares for the wing-off configuration. With this information, a quantitative comparison between both support systems could be made with reasonable certainty.

After the centerplate (described in Section III C) was installed, the body fairing was fastened onto the upper edge of the plate and wind-off weight tares were taken (see Section IV C). Wind-on runs were then conducted for Q values of 40, 30 and 20 psf, respectively.

The body fairing was removed from the tunnel, the wing-on center section was fitted, and then the entire wing-body assembly was reinstalled onto the plate support in the tunnel test section. A complete repetition of the previous wing-off steps was then performed.

Incorporation of tares for both wing-off/on cases was accomplished by means of computer programs presented in a following section.

## F. THEORETICALLY EXPECTED RESULTS

Independent of mounting considerations, one should have an engineering feel for the expected results of a finite wing with a symmetrical airfoil. Section data on NACA 63-010 and

NACA 63-009 airfoils (Ref. 6) were the basis for approximate estimates of the ideal, free-air behavior of the calibration wing. The lift curve, drag polar and pitching moment curve will be reviewed in that order.

The referenced section data indicated a linear section lift curve slope of approximately 0.10 $\text{deg}^{-1}$. Correction for a wing aspect ratio of six yielded a three-dimensional lift curve slope on the order of 0.073 $\text{deg}^{-1}$ (Ref. 7). Of course, a finite wing's $C_{L_{max}}$ will occur at an angle of attack several degrees higher than the 10 degree value observed in the sectional data. However, approximately the same maximum lift coefficient would be expected for both two- and three-dimensional wing cases when operated with approximately the same Reynolds number values. Further inspection of symmetrical airfoil behavior indicates a lift curve symmetric about the origin with a zero lift angle ($\alpha_{oL}$) of zero.

The drag polar (plot of $C_L$ vs. $C_D$) is also symmetric, but about the coefficient of drag axis with a zero lift drag ($C_{D_o}$) value of approximately 0.008 (80 drag counts). The $C_{D_o}$ values of both the two- and three-dimensional wing cases should be identical, since induced drag is not a factor at zero lift for an untwisted and uncambered wing. Note that the $C_{D_o}$ estimate of 0.008 was based for a model with standard roughness, and no drag-bucket phenomenon (characteristic of laminar flow airfoils) was expected.

As a check on the magnitude of the drag tares for the centerplate and fairing, an estimate of the turbulent skin friction drag at Q = 40 psf in sea-level conditions was performed.

Plate Reynolds number:

$$(R_N)_{\text{Plate}} = \frac{Vx}{\nu} = \frac{(183.5\ \text{ft/sec})(1.67\ \text{ft})}{0.000158\ \text{ft}^2/\text{sec}} \cong 1.94\text{x}10^6$$

Body fairing Reynolds number:

$$(R_N)_{\text{Fairing}} \cong 1.94\text{x}10^6 * \frac{(2.67\ \text{ft})}{(1.67\ \text{ft})} \cong 3.10\text{x}10^6$$

If the entire plate were in turbulent flow, then skin-friction drag would be:

$$D_{f_p} = 2 \text{ x } Q \text{ x } S \text{ x } C_f$$

where

$$C_f = 0.455 \text{ x } (\log_{10} R_N)^{-2.58}$$

Hence $D_{f_p} = 2 \text{ x } (40\ \text{psf})(1.18\ \text{ft}^2)(0.00396) = 0.374\ \text{lb}$

If the entire body fairing were in turbulent flow, then:

$$D_{f_F} = 1 \text{ x } (40\ \text{psf})(1.40\ \text{ft}^2)(0.00379) = 0.212\ \text{lb}$$

where $S_f$ = cylindrical approximation to body fairing wetted area! Total drag then becomes:

$$D_T = D_{f_p} + D_{f_F} = 0.586\ \text{lb}$$

And the drag coefficient, referenced to wing area, would be:

$$C_{D_T} = \frac{D_T}{QS} = \frac{0.586 \text{ lb}}{(40 \text{ psf})(1.5 \text{ ft}^2)} = 0.0098$$

The turbulent flow approximation was assumed based upon the observation that the leading edge of the centerplate had a 0.030-inch bluntness for safety and ease of fabrication, while the plate surface was smooth but unpolished for the experiment.

Wing-alone stability as measured by the slope $dC_{M_{\bar{c}/4}}/dC_L$ provides a direct indication of the wing aerodynamic center location. The slope would be zero if the aerodynamic center were located at the wing quarter-MAC location. Additionally, the symmetry of the airfoil would lead one to expect a zero value of $C_{M_{\bar{c}/4}}$ at zero left; i.e., $C_{M_o} = 0$.

# V. PRESENTATION OF DATA

A summary of all the wind tunnel runs performed in conjunction with this study are listed in Table 1. Corrected aerodynamic data for the runs at Q = 40, 30, and 20 psf are presented in that order. Each tabulated run in this section represents reduced data for 27 geometric angle of attack conditions. The geometric angle of attack was varied from minus six degrees to plus fourteen degrees in one degree increments. As a repeatability check within each run, the angle of attack was then returned to plus six degrees and reduced in two degree increments to minus four degrees. The data presented for each geometric angle of attack condition were the aerodynamic angle of attack, Q, $C_L$, $C_D$, and $C_{M\bar{c}/4}$. The three-strut configuration data are corrected only for weight tares. Centerplate configuration data are corrected for aerodynamic tares as well as weight tares, and tables of the reduced aerodynamic tare coefficients are presented immediately behind their respective run data.

Three-strut run 051501 and centerplate run 052703 at Q = 40 psf were selected as the most representative because of the higher nominal Q and subsequent removal of any possible taxing of balance resolution. Plots of $C_L$ vs. $\alpha$, $C_D$ and $C_{M\bar{c}/4}$ were constructed for these data and immediately precede the table for their respective runs. The plots of run 051501

were reproduced on the plots for run 052703 to facilitate a direct comparison of calibration wing performance on each mounting system.

The reduction programs and storage records are presented in later sections of this report. The raw data are displayed in Appendix C.

Reference is not included on Reynolds number since the runs were made in virtually identical conditions and no scaling correlations were attempted.

## Table I

## Wind-Tunnel Run Log

| DATE | RUN # | NOMINAL Q (psf) | PURPOSE |
|---|---|---|---|
| 5-15-77 | 051577 | 0 | Weight tare, calibration wing on three-strut mount |
| " | 051501 | 40 | Data for $C_L$ vs., $C_D$, $C_{M\bar{c}/4}$ |
| 5-18-77 | 051877 | 0 | Weight tare, calibration wing on three-strut mount |
| " | 051801 | 40 | Data for $C_L$ vs., $C_D$, $C_{M\bar{c}/4}$ |
| " | 051802 | 30 | " " |
| " | 051803 | 20 | " " |
| 5-24-77 | --- | 8-58 | Q calibration, plate fairing in clear tunnel |
| 5-26-77 | 052677 | 0 | Weight tare, plate plus fairing, wing-off |
| " | 052601 | 20 | Aerodynamic tares for $C_L$, $C_D$, $C_{M\bar{c}/4}$ |
| " | 052602 | 40 | " " |
| " | 052603 | 30 | " " |
| 5-27-77 | 05277 | 0 | Weight tare, plate plus fairing, wing-on |
| " | 052701 | 20 | Data for $C_L$ vs., $C_D$, $C_{M\bar{c}/4}$ |
| " | 052702 | 30 | " " |
| " | 052703 | 40 | " " |

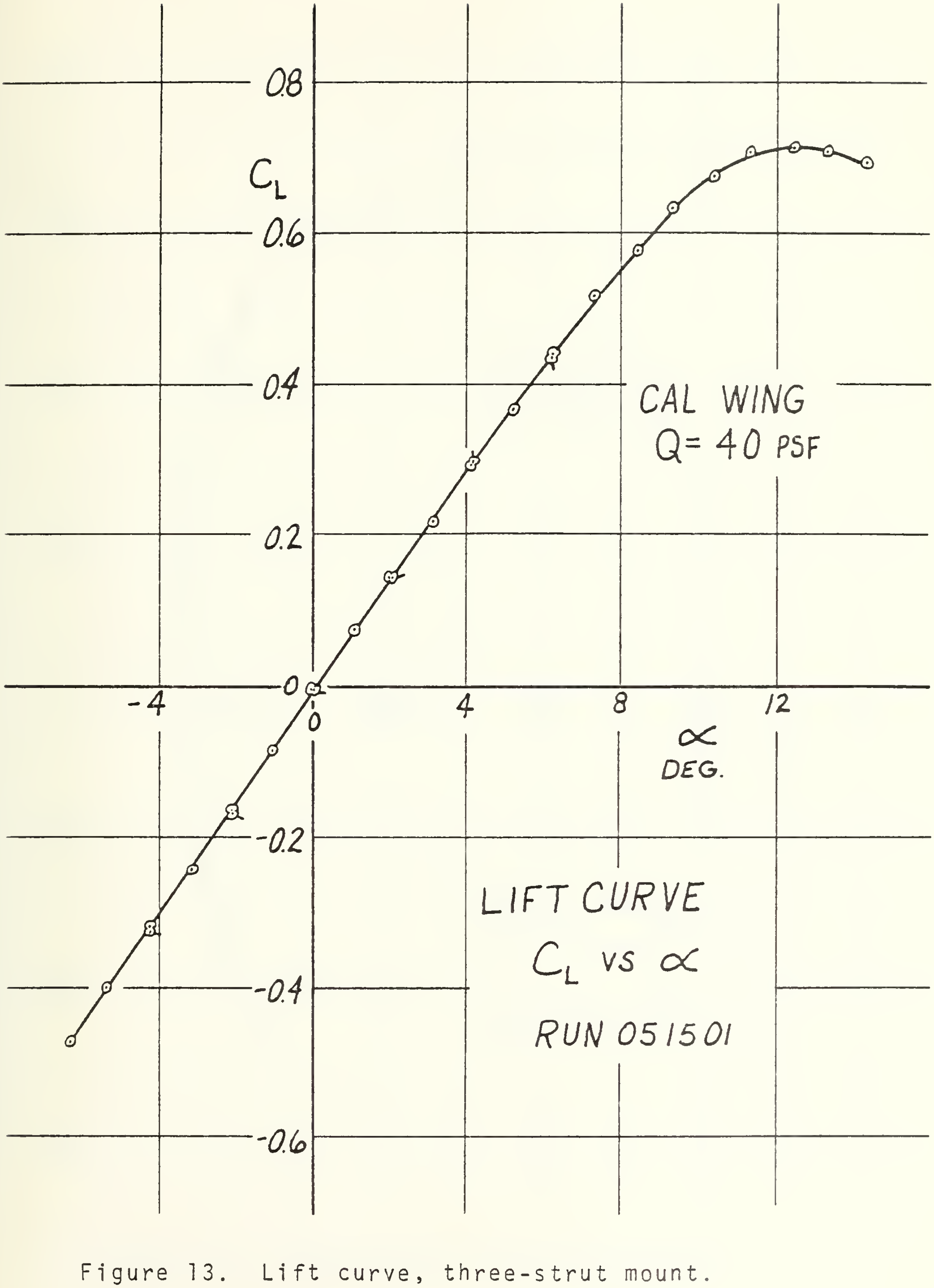


Figure 13. Lift curve, three-strut mount.

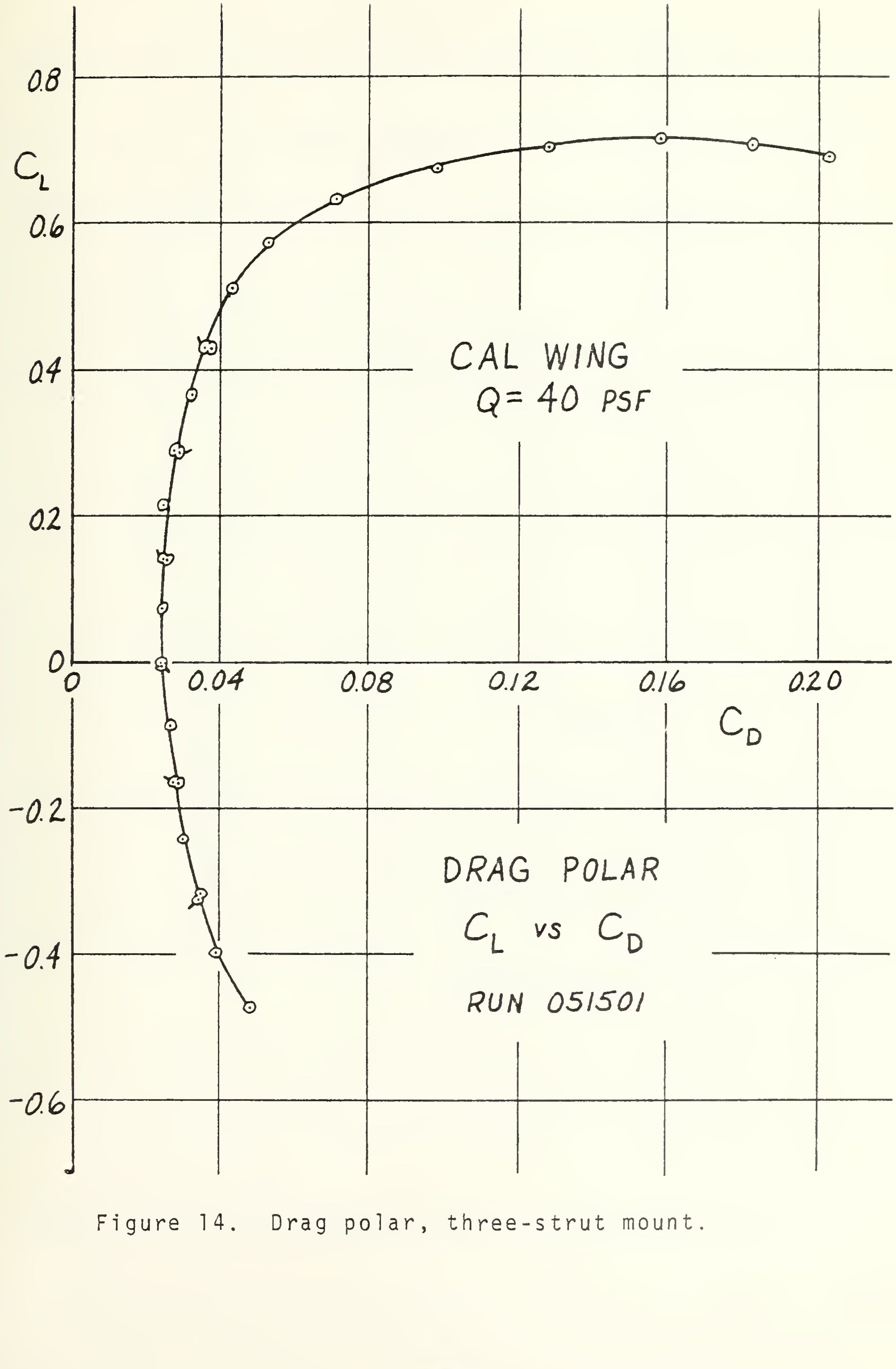


Figure 14. Drag polar, three-strut mount.

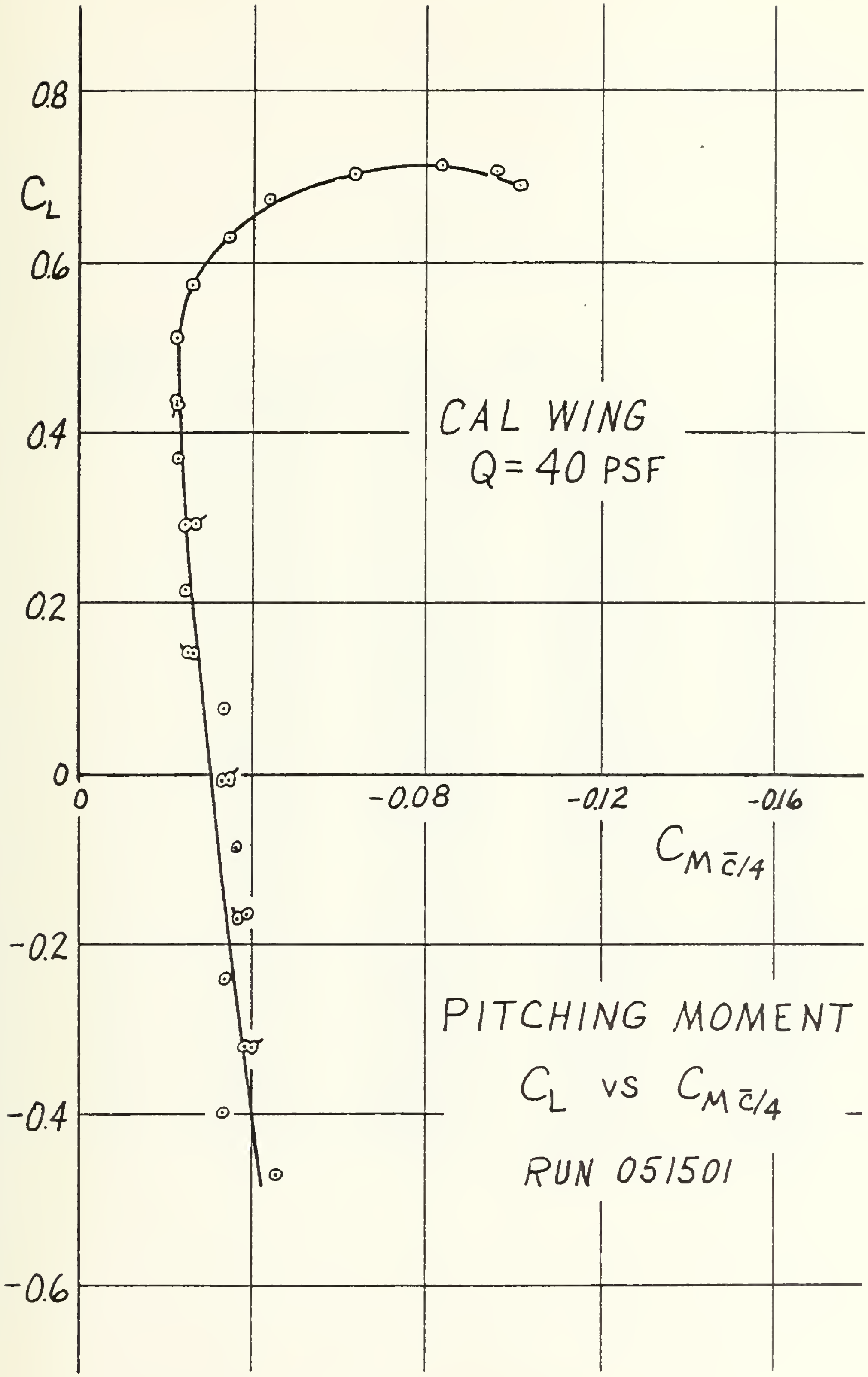


Figure 15. Pitching moment curve, three-strut mount.

## TABLE II

```
CORRECTED DATA OF RUN # 51501
ROW #    AOA(DEG)   Q(PSF)        CL          CD        CM-C/4
    1   -0.8917   41.2018    -0.4769     0.0468     -0.0395
    2   -0.7407   41.4827    -0.3968     0.0389     -0.0336
    3   -0.5911   41.2767    -0.3166     0.0348     -0.0374
    4   -0.4446   40.8366    -0.2406     0.0299     -0.0328
    5   -0.2967   41.8011    -0.1640     0.0281     -0.0375
    6   -0.1485   42.2318    -0.0836     0.0263     -0.0352
    7   -0.0031   41.8853    -0.0071     0.0248     -0.0320
    8    0.1474   41.4827     0.0750     0.0250     -0.0324
    9    0.2836   41.9228     0.1420     0.0247     -0.0265
   10    0.4326   42.2599     0.2190     0.0262     -0.0254
   11    0.5792   42.6157     0.2927     0.0288     -0.0236
   12    0.7228   42.9434     0.3662     0.0322     -0.0223
   13    0.8676   42.4471     0.4365     0.0372     -0.0215
   14    1.0161   42.8030     0.5133     0.0427     -0.0214
   15    1.1546   42.7280     0.5774     0.0532     -0.0243
   16    1.2849   42.0913     0.6332     0.0714     -0.0342
   17    1.4132   41.8011     0.6773     0.0970     -0.0428
   18    1.5335   41.0520     0.7038     0.1275     -0.0631
   19    1.6438   40.9490     0.7158     0.1576     -0.0835
   20    1.7326   41.2299     0.7073     0.1816     -0.0973
   21    1.8235   40.2093     0.6940     0.2032     -0.1119
   22    0.8661   42.0258     0.4339     0.0367     -0.0212
   23    0.5771   41.1456     0.2874     0.0293     -0.0268
   24    0.2875   41.2486     0.1429     0.0243     -0.0258
   25   -0.0029   40.7898    -0.0086     0.0249     -0.0335
   26   -0.3003   39.3291    -0.1670     0.0273     -0.0350
   27   -0.5917   39.9003    -0.3230     0.0344     -0.0390
```

## TABLE III

CORRECTED DATA OF RUN # 51801

| ROW # | AOA(DEG) | Q(PSF) | CL | CD | CM-C/4 |
|---|---|---|---|---|---|
| 1 | -0.8874 | 41.0404 | -0.4754 | 0.0453 | -0.0328 |
| 2 | -0.7446 | 40.0947 | -0.4031 | 0.0392 | -0.0324 |
| 3 | -0.5949 | 40.9936 | -0.3228 | 0.0331 | -0.0297 |
| 4 | -0.4466 | 39.6453 | -0.2418 | 0.0288 | -0.0270 |
| 5 | -0.2976 | 39.6172 | -0.1654 | 0.0271 | -0.0312 |
| 6 | -0.1532 | 41.1341 | -0.0914 | 0.0247 | -0.0272 |
| 7 | -0.0034 | 41.1060 | -0.0076 | 0.0244 | -0.0290 |
| 8 | 0.1420 | 40.9936 | 0.0664 | 0.0245 | -0.0281 |
| 9 | 0.2879 | 41.9299 | 0.1438 | 0.0249 | -0.0262 |
| 10 | 0.4352 | 41.5273 | 0.2215 | 0.0259 | -0.0218 |
| 11 | 0.5798 | 41.8738 | 0.2935 | 0.0288 | -0.0232 |
| 12 | 0.7212 | 41.6678 | 0.3635 | 0.0330 | -0.0251 |
| 13 | 0.8696 | 41.7801 | 0.4394 | 0.0374 | -0.0232 |
| 14 | 1.0127 | 41.6210 | 0.5119 | 0.0429 | -0.0209 |
| 15 | 1.1516 | 42.0236 | 0.5750 | 0.0531 | -0.0222 |
| 16 | 1.2873 | 41.5929 | 0.6334 | 0.0725 | -0.0356 |
| 17 | 1.4129 | 41.7240 | 0.6767 | 0.0983 | -0.0449 |
| 18 | 1.5317 | 41.4711 | 0.7042 | 0.1612 | -0.2365 |
| 19 | 1.6410 | 41.6490 | 0.7210 | 0.1569 | -0.0838 |
| 20 | 1.7367 | 40.6752 | 0.7157 | 0.1817 | -0.0975 |
| 21 | 1.8167 | 40.5442 | 0.6829 | 0.2011 | -0.1102 |
| 22 | 0.8644 | 41.3213 | 0.4360 | 0.0374 | -0.0224 |
| 23 | 0.5786 | 42.0142 | 0.2916 | 0.0290 | -0.0235 |
| 24 | 0.2849 | 41.2183 | 0.1388 | 0.0250 | -0.0259 |
| 25 | -0.0002 | 40.9842 | -0.0023 | 0.0245 | -0.0282 |
| 26 | -0.2983 | 39.7576 | -0.1665 | 0.0270 | -0.0318 |
| 27 | -0.5982 | 40.6565 | -0.3282 | 0.0344 | -0.0350 |

# TABLE IV

```
CORRECTED DATA OF RUN # 51802
ROW #    AOA(DEG)   Q(PSF)        CL           CD        CM-C/4
    1   -0.8828    30.2724     -0.4721      0.0445     -0.0335
    2   -0.7404    29.9447     -0.4000      0.0374     -0.0276
    3   -0.5964    29.7294     -0.3255      0.0324     -0.0296
    4   -0.4449    30.2350     -0.2388      0.0275     -0.0246
    5   -0.2933    29.6732     -0.1582      0.0256     -0.0282
    6   -0.1563    30.0103     -0.0864      0.0230     -0.0225
    7   -0.0048    30.3848     -0.0098      0.0221     -0.0214
    8    0.1440    29.7106      0.0696      0.0224     -0.0222
    9    0.2906    30.7032      0.1481      0.0234     -0.0227
   10    0.4333    30.6751      0.2199      0.0249     -0.0197
   11    0.5767    30.7125      0.2887      0.0275     -0.0179
   12    0.7291    30.7500      0.3742      0.0317     -0.0191
   13    0.8676    31.0028      0.4411      0.0358     -0.0178
   14    1.0154    30.7032      0.5161      0.0433     -0.0221
   15    1.1509    30.4035      0.5761      0.0541     -0.0226
   16    1.2892    30.6998      0.6316      0.0712     -0.0204
   17    1.4138    30.7593      0.6732      0.0994     -0.0453
   18    1.5309    30.2537      0.7078      0.1743     -0.3904
   19    1.6379    30.0758      0.7160      0.1578     -0.0858
   20    1.7313    30.2537      0.7101      0.1818     -0.0980
   21    1.8228    30.4316      0.6929      0.2042     -0.1151
   22    0.8648    30.9372      0.4368      0.0370     -0.0240
   23    0.5796    30.5533      0.2932      0.0284     -0.0231
   24    0.2834    31.0028      0.1364      0.0247     -0.0289
   25   -0.0047    30.8998     -0.0096      0.0236     -0.0284
   26   -0.2946    30.7593     -0.1606      0.0264     -0.0334
   27   -0.5976    30.4410     -0.3276      0.0326     -0.0288
```

## TABLE V

```
CORRECTED DATA OF RUN # 51803
ROW #    AOA(DEG)   Q(PSF)         CL           CD         CM-C/4
    1   -0.9016   20.1786    -0.4986       0.0424     -0.0343
    2   -0.7527   20.4595    -0.4203       0.0361     -0.0307
    3   -0.6109   20.7966    -0.3491       0.0317     -0.0317
    4   -0.4609   20.3752    -0.2651       0.0251     -0.0187
    5   -0.3103   20.2442    -0.1863       0.0243     -0.0293
    6   -0.1575   20.6374    -0.0983       0.0217     -0.0221
    7   -0.0115   20.7123    -0.0209       0.0227     -0.0290
    8    0.1308   20.7966     0.0529       0.0219     -0.0239
    9    0.2847   20.8809     0.1392       0.0225     -0.0217
   10    0.4299   20.6749     0.2144       0.0235     -0.0146
   11    0.5719   20.8060     0.2830       0.0260     -0.0117
   12    0.7269   21.0307     0.3728       0.0308     -0.0172
   13    0.8723   20.6749     0.4440       0.0340     -0.0080
   14    1.0158   21.1056     0.5170       0.0414     -0.0107
   15    1.1590   20.6468     0.5853       0.0536     -0.0117
   16    1.2797   20.9277     0.6215       0.0678     -0.0076
   17    1.4087   21.0213     0.6697       0.0971     -0.0205
   18    1.5226   20.3846     0.6926       0.1946     -0.3953
   19    1.6317   20.5251     0.7058       0.1567     -0.0830
   20    1.7286   20.5157     0.7008       0.1828     -0.1032
   21    1.8135   20.5906     0.6777       0.2031     -0.1187
   22    0.8724   20.8809     0.4439       0.0355     -0.0180
   23    0.5815   20.6936     0.2966       0.0260     -0.0148
   24    0.2778   20.7779     0.1273       0.0226     -0.0202
   25   -0.0131   20.5906    -0.0235       0.0219     -0.0246
   26   -0.3105   20.7779    -0.1868       0.0250     -0.0319
   27   -0.6123   20.3565    -0.3516       0.0313     -0.0265
```

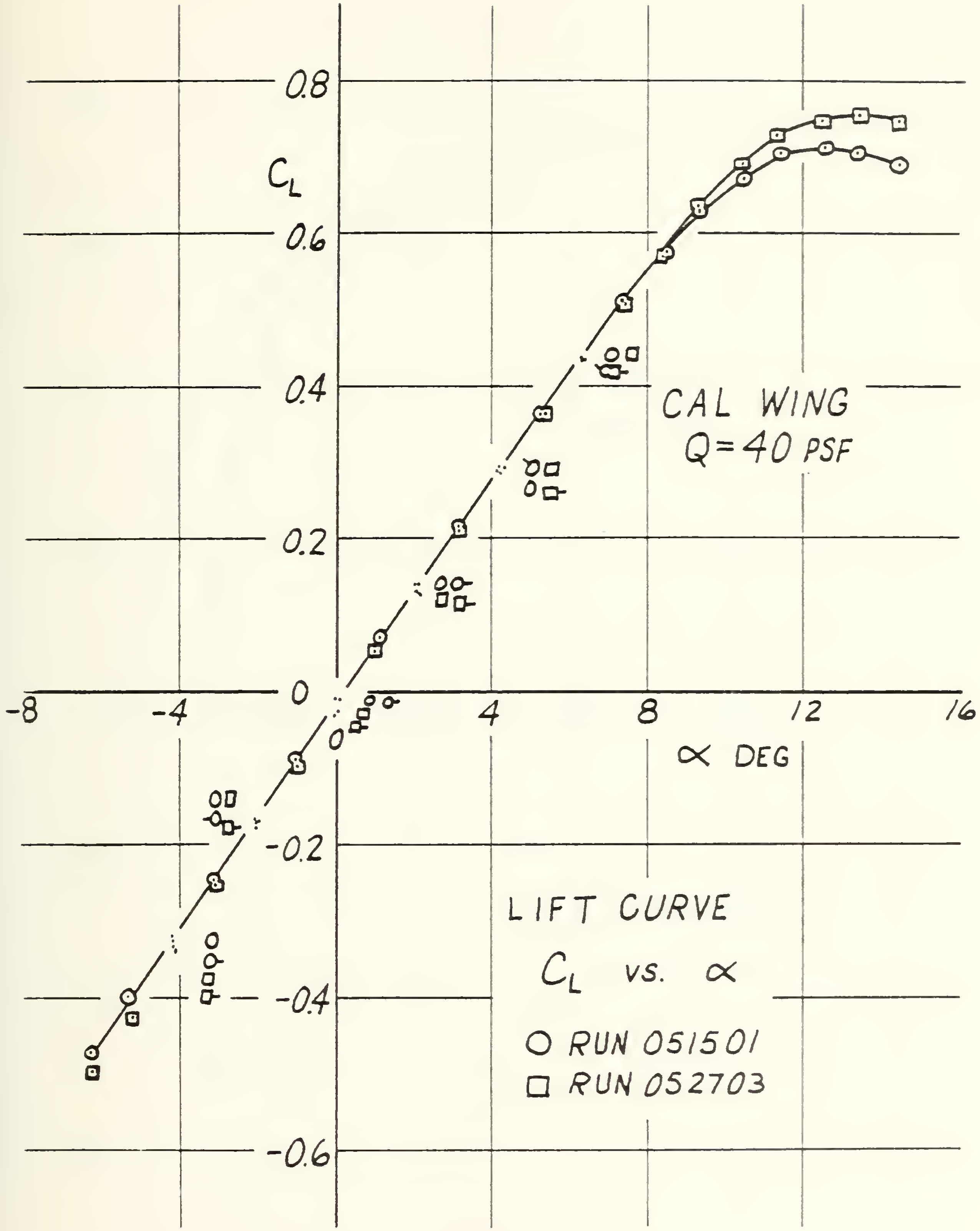


Figure 16. Lift curve, centerplate mount.

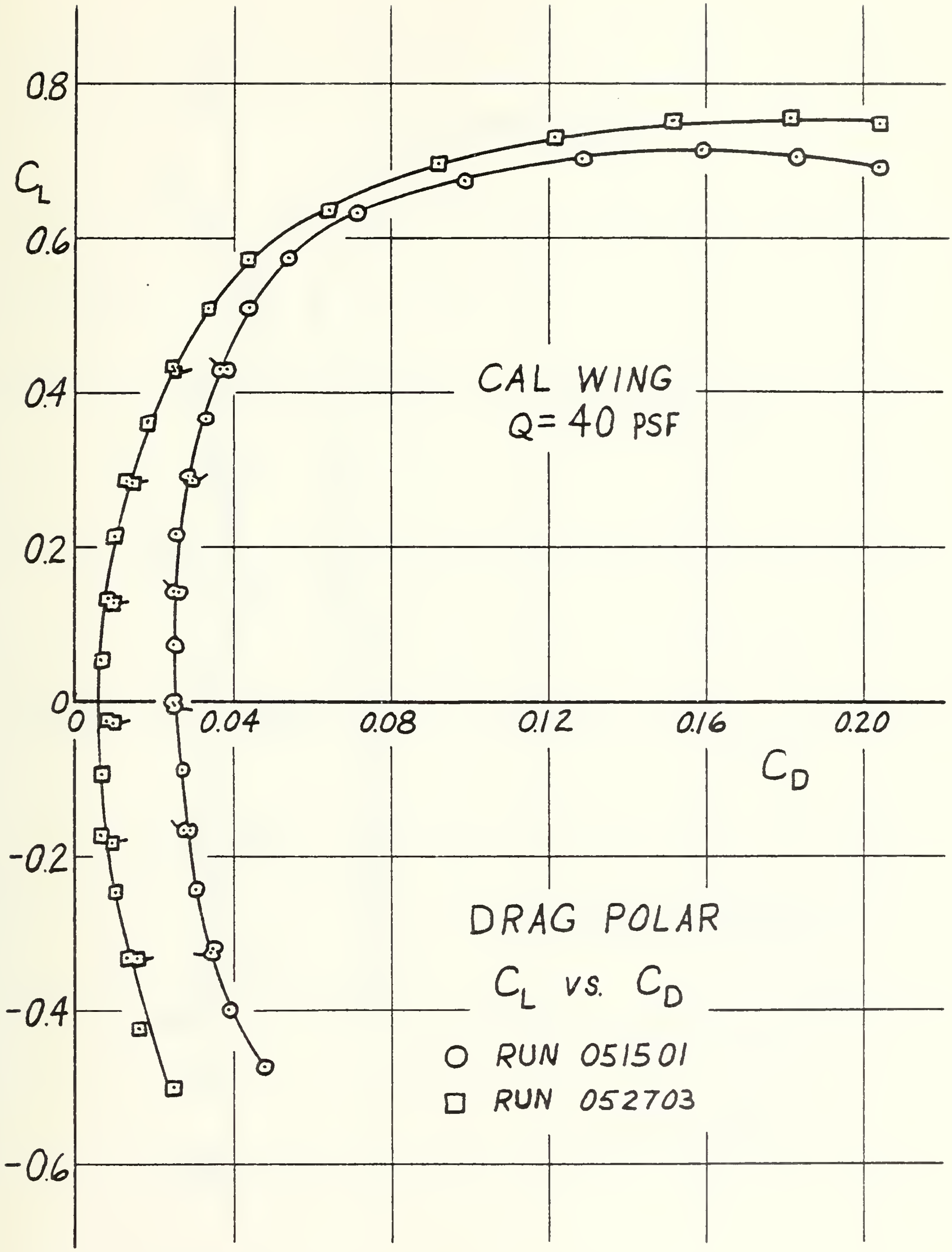


Figure 17. Drag polar, centerplate mount.

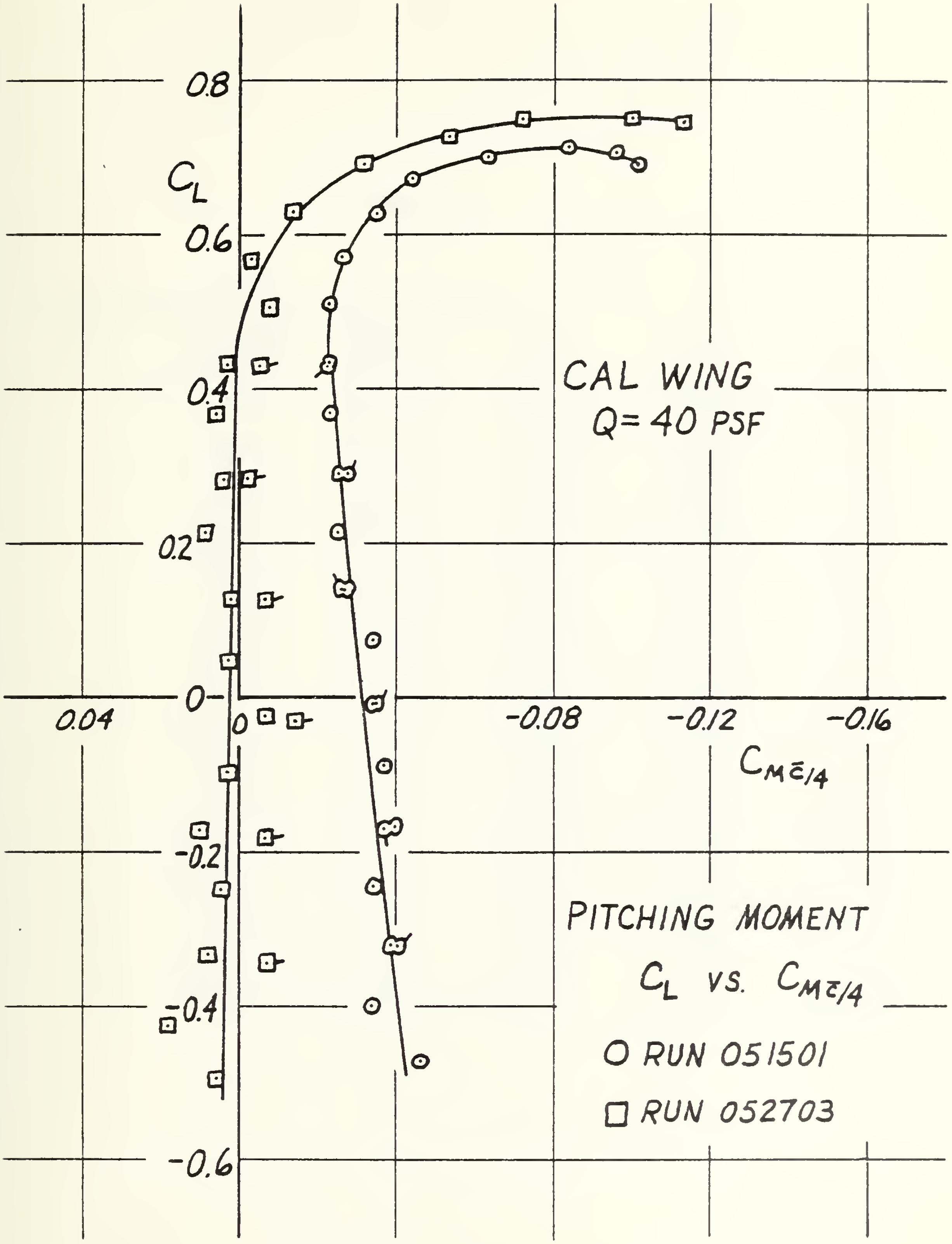


Figure 18. Pitching moment curve, centerplate mount.

## TABLE VI

```
CORRECTED DATA OF RUN # 52703
ROW #   AOA(DEG)   Q(PSF)        CL          CD        CM-C/4
    1   -6.2505   39.4395    -0.4958      0.0248      0.0074
    2   -5.2190   39.7807    -0.4212      0.0169      0.0191
    3   -4.1657   39.4495    -0.3338      0.0130      0.0084
    4   -3.1060   40.1219    -0.2458      0.0099      0.0049
    5   -2.0654   40.0216    -0.1728      0.0065      0.0100
    6   -1.0133   39.8610    -0.0983      0.0069      0.0028
    7   -0.0023   40.5836    -0.0237      0.0083     -0.0072
    8    1.0470   40.6839     0.0525      0.0070      0.0029
    9    2.0834   40.7542     0.1334      0.0083      0.0022
   10    3.1529   40.7140     0.2145      0.0097      0.0089
   11    4.1833   40.5735     0.2840      0.0133      0.0046
   12    5.2486   40.8545     0.3647      0.0178      0.0073
   13    6.2822   41.1657     0.4362      0.0238      0.0043
   14    7.3203   40.7442     0.5085      0.0332     -0.0076
   15    8.3716   40.8746     0.5729      0.0438     -0.0009
   16    9.4025   41.3664     0.6384      0.0637     -0.0107
   17   10.4536   40.7542     0.6943      0.0922     -0.0291
   18   11.4654   40.7743     0.7299      0.1215     -0.0525
   19   12.4795   40.4832     0.7530      0.1509     -0.0712
   20   13.4730   39.8911     0.7588      0.1815     -0.1003
   21   14.4694   40.1219     0.7528      0.2043     -0.1143
   22    6.2816   41.0452     0.4310      0.0250     -0.0040
   23    4.1850   40.4531     0.2851      0.0144     -0.0018
   24    2.0951   40.9047     0.1280      0.0095     -0.0071
   25   -0.0051   41.1657    -0.0283      0.0094     -0.0149
   26   -2.0721   39.9915    -0.1821      0.0095     -0.0083
   27   -4.1862   40.4832    -0.3412      0.0157     -0.0066
```

# TABLE VII

```
AERODYNAMIC TARES OF RUN # 52703
ROW #    AOA(DEG)   Q(PSF)      DCL         DCD        DCM-C/4
    1   -6.2505   39.4395   -0.0101    -0.0092     0.0203
    2   -5.2190   39.7807   -0.0121    -0.0106     0.0281
    3   -4.1657   39.4495   -0.0085    -0.0111     0.0280
    4   -3.1060   40.1219   -0.0117    -0.0109     0.0250
    5   -2.0654   40.0216   -0.0134    -0.0102     0.0197
    6   -1.0133   39.8610   -0.0145    -0.0102     0.0170
    7   -0.0023   40.5836   -0.0172    -0.0094     0.0100
    8    1.0470   40.6839   -0.0157    -0.0100     0.0074
    9    2.0834   40.7542   -0.0178    -0.0098     0.0049
   10    3.1529   40.7140   -0.0152    -0.0103     0.0073
   11    4.1833   40.5735   -0.0172    -0.0106     0.0062
   12    5.2486   40.8545   -0.0162    -0.0104     0.0068
   13    6.2822   41.1657   -0.0188    -0.0106     0.0061
   14    7.3203   40.7442   -0.0213    -0.0103     0.0013
   15    8.3716   40.8746   -0.0214    -0.0103     0.0013
   16    9.4025   41.3664   -0.0230    -0.0112     0.0048
   17   10.4536   40.7542   -0.0214    -0.0111     0.0031
   18   11.4654   40.7743   -0.0237    -0.0112     0.0020
   19   12.4795   40.4832   -0.0243    -0.0118     0.0041
   20   13.4730   39.8911   -0.0246    -0.0115     0.0012
   21   14.4694   40.1219   -0.0248    -0.0119     0.0005
   22    6.2810   41.0452   -0.0207    -0.0099    -0.0004
   23    4.1850   40.4531   -0.0187    -0.0100     0.0026
   24    2.0951   40.9047   -0.0174    -0.0090    -0.0031
   25   -0.0051   41.1657   -0.0170    -0.0092     0.0082
   26   -2.0721   39.9915   -0.0171    -0.0087     0.0099
   27   -4.1862   40.4832   -0.0158    -0.0084     0.0095
```

# TABLE VIII

CORRECTED DATA OF RUN # 52702

| ROW # | AOA(DEG) | Q(PSF) | CL | CD | CM-C/4 |
|---|---|---|---|---|---|
| 1 | -6.2427 | 30.1529 | -0.4829 | 0.0238 | 0.0093 |
| 2 | -5.2126 | 30.8980 | -0.4108 | 0.0173 | 0.0187 |
| 3 | -4.1453 | 30.3039 | -0.3283 | 0.0108 | 0.0256 |
| 4 | -3.1054 | 30.6865 | -0.2464 | 0.0085 | 0.0096 |
| 5 | -2.0594 | 30.3945 | -0.1629 | 0.0066 | 0.0110 |
| 6 | -1.0084 | 30.5355 | -0.0894 | 0.0055 | 0.0101 |
| 7 | 0.0065 | 30.7369 | -0.0093 | 0.0073 | 0.0015 |
| 8 | 1.0417 | 30.5959 | 0.0688 | 0.0083 | -0.0038 |
| 9 | 2.0987 | 30.6060 | 0.1535 | 0.0080 | 0.0064 |
| 10 | 3.1618 | 30.7570 | 0.2275 | 0.0078 | 0.0267 |
| 11 | 4.1932 | 30.7671 | 0.3019 | 0.0112 | 0.0213 |
| 12 | 5.2570 | 30.8778 | 0.3769 | 0.0158 | 0.0257 |
| 13 | 6.2951 | 30.9785 | 0.4558 | 0.0226 | 0.0176 |
| 14 | 7.3239 | 30.7872 | 0.5177 | 0.0328 | 0.0013 |
| 15 | 8.3844 | 30.7570 | 0.5939 | 0.0452 | 0.0098 |
| 16 | 9.4051 | 30.6261 | 0.6443 | 0.0631 | 0.0027 |
| 17 | 10.4486 | 30.5858 | 0.7023 | 0.0922 | -0.0179 |
| 18 | 11.4685 | 30.5556 | 0.7351 | 0.1215 | -0.0430 |
| 19 | 12.4819 | 30.5758 | 0.7570 | 0.1514 | -0.0634 |
| 20 | 13.4732 | 30.1227 | 0.7591 | 0.1798 | -0.0897 |
| 21 | 14.4732 | 30.4549 | 0.7592 | 0.2059 | -0.1175 |
| 22 | 6.2910 | 30.5456 | 0.4491 | 0.0245 | -0.0015 |
| 23 | 4.1905 | 30.9061 | 0.2959 | 0.0132 | 0.0022 |
| 24 | 2.0844 | 30.4046 | 0.1301 | 0.0100 | -0.0094 |
| 25 | 0.0020 | 30.7570 | -0.0167 | 0.0101 | -0.0180 |
| 26 | -2.0680 | 30.7369 | -0.1750 | 0.0092 | -0.0076 |
| 27 | -4.1848 | 30.3643 | -0.3372 | 0.0136 | 0.0088 |

## TABLE IX

AERODYNAMIC TARES OF RUN # 52702

| ROW # | AOA(DEG) | Q(PSF) | DCL | DCD | DCM-C/4 |
|---|---|---|---|---|---|
| 1 | -6.2427 | 30.1529 | -0.0067 | -0.0094 | 0.0188 |
| 2 | -5.2126 | 30.8980 | -0.0097 | -0.0104 | 0.0240 |
| 3 | -4.1453 | 30.3039 | -0.0078 | -0.0119 | 0.0331 |
| 4 | -3.1054 | 30.6865 | -0.0087 | -0.0115 | 0.0287 |
| 5 | -2.0594 | 30.3945 | -0.0127 | -0.0101 | 0.0197 |
| 6 | -1.0084 | 30.5355 | -0.0101 | -0.0116 | 0.0250 |
| 7 | 0.0065 | 30.7369 | -0.0110 | -0.0104 | 0.0179 |
| 8 | 1.0417 | 30.5959 | -0.0094 | -0.0098 | 0.0054 |
| 9 | 2.0987 | 30.6060 | -0.0098 | -0.0109 | 0.0093 |
| 10 | 3.1618 | 30.7570 | -0.0124 | -0.0109 | 0.0104 |
| 11 | 4.1932 | 30.7671 | -0.0145 | -0.0114 | 0.0093 |
| 12 | 5.2570 | 30.8778 | -0.0121 | -0.0119 | 0.0145 |
| 13 | 6.2951 | 30.9785 | -0.0143 | -0.0116 | 0.0119 |
| 14 | 7.3239 | 30.7872 | -0.0149 | -0.0114 | 0.0068 |
| 15 | 8.3844 | 30.7570 | -0.0182 | -0.0120 | 0.0083 |
| 16 | 9.4051 | 30.6261 | -0.0199 | -0.0130 | 0.0115 |
| 17 | 10.4486 | 30.5858 | -0.0190 | -0.0124 | 0.0077 |
| 18 | 11.4685 | 30.5556 | -0.0210 | -0.0124 | 0.0054 |
| 19 | 12.4819 | 30.5758 | -0.0219 | -0.0129 | 0.0062 |
| 20 | 13.4732 | 30.1227 | -0.0223 | -0.0121 | 0.0010 |
| 21 | 14.4732 | 30.4549 | -0.0251 | -0.0120 | -0.0045 |
| 22 | 6.2910 | 30.5456 | -0.0187 | -0.0107 | 0.0000 |
| 23 | 4.1905 | 30.9081 | -0.0154 | -0.0102 | -0.0006 |
| 24 | 2.0844 | 30.4046 | -0.0156 | -0.0089 | -0.0078 |
| 25 | 0.0020 | 30.7570 | -0.0175 | -0.0093 | 0.0080 |
| 26 | -2.0688 | 30.7369 | -0.0151 | -0.0089 | 0.0085 |
| 27 | -4.1848 | 30.3643 | -0.0138 | -0.0088 | 0.0106 |

## TABLE X

CORRECTED DATA OF RUN # 52701

| ROW # | AOA(DEG) | Q(PSF) | CL | CD | CM-C/4 |
|---|---|---|---|---|---|
| 1 | -6.2698 | 20.2376 | -0.5061 | 0.0256 | 0.0066 |
| 2 | -5.2260 | 20.0659 | -0.4310 | 0.0199 | 0.0054 |
| 3 | -4.1855 | 19.9346 | -0.3581 | 0.0141 | 0.0030 |
| 4 | -3.1238 | 19.6519 | -0.2751 | 0.0103 | 0.0095 |
| 5 | -2.0751 | 20.0659 | -0.1870 | 0.0057 | 0.0160 |
| 6 | -1.0229 | 19.9346 | -0.1132 | 0.0067 | 0.0068 |
| 7 | -0.0059 | 20.1265 | -0.0297 | 0.0085 | -0.0038 |
| 8 | 1.0464 | 19.9043 | 0.0515 | 0.0068 | 0.0157 |
| 9 | 2.0796 | 20.1568 | 0.1272 | 0.0041 | 0.0337 |
| 10 | 3.1475 | 20.0962 | 0.2073 | 0.0058 | 0.0422 |
| 11 | 4 1750 | 20.1770 | 0.2721 | 0.0086 | 0.0403 |
| 12 | 5.2513 | 20.0457 | 0.3709 | 0.0144 | 0.0376 |
| 13 | 6.2841 | 20.2275 | 0.4378 | 0.0204 | 0.0355 |
| 14 | 7.3462 | 19.9952 | 0.5149 | 0.0319 | 0.0106 |
| 15 | 8.3705 | 20.1770 | 0.5727 | 0.0428 | 0.0195 |
| 16 | 9.4025 | 20.0760 | 0.6400 | 0.0654 | 0.0033 |
| 17 | 10.4337 | 19.7428 | 0.6944 | 0.0951 | -0.0168 |
| 18 | 11.4662 | 19.9447 | 0.7312 | 0.1232 | -0.0373 |
| 19 | 12.4792 | 19.7629 | 0.7526 | 0.1531 | -0.0572 |
| 20 | 13.4718 | 19.8538 | 0.7568 | 0.1829 | -0.0900 |
| 21 | 14.4691 | 19.6519 | 0.7524 | 0.2050 | -0.1016 |
| 22 | 6.2839 | 20.0558 | 0.4373 | 0.0228 | 0.0095 |
| 23 | 4.1783 | 20.3386 | 0.2758 | 0.0113 | 0.0194 |
| 24 | 2.0749 | 19.8437 | 0.1195 | 0.0073 | 0.0084 |
| 25 | -0.0034 | 20.3284 | -0.0256 | 0.0118 | -0.0257 |
| 26 | -2.0942 | 20.1265 | -0.2183 | 0.0094 | -0.0056 |
| 27 | -4.2092 | 19.9548 | -0.3773 | 0.0161 | -0.0058 |

# TABLE XI

```
AERODYNAMIC TARES OF RUN # 52701
ROW #   AOA(DEG)  Q(PSF)      DCL        DCD       DCM-C/4
    1  -6.2698   20.2376   -0.0084    -0.0085     0.0173
    2  -5.2260   20.0659   -0.0106    -0.0076     0.0073
    3  -4.1855   19.9346   -0.0096    -0.0088     0.0093
    4  -3.1238   19.6519   -0.0138    -0.0096     0.0183
    5  -2.0751   20.0659   -0.0148    -0.0104     0.0285
    6  -1.0229   19.9346   -0.0125    -0.0114     0.0292
    7  -0.0059   20.1265   -0.0166    -0.0101     0.0200
    8   1.0464   19.9043   -0.0129    -0.0105     0.0134
    9   2.0796   20.1568   -0.0169    -0.0134     0.0243
   10   3.1475   20.0962   -0.0147    -0.0138     0.0297
   11   4.1750   20.1770   -0.0142    -0.0145     0.0295
   12   5.2513   20.0457   -0.0112    -0.0135     0.0266
   13   6.2841   20.2275   -0.0170    -0.0136     0.0267
   14   7.3462   19.9952   -0.0170    -0.0117     0.0107
   15   8.3705   20.1770   -0.0175    -0.0124     0.0146
   16   9.4025   20.0760   -0.0210    -0.0140     0.0215
   17  10.4337   19.7428   -0.0183    -0.0121     0.0104
   18  11.4662   19.9447   -0.0199    -0.0133     0.0148
   19  12.4792   19.7629   -0.0190    -0.0136     0.0163
   20  13.4718   19.8538   -0.0200    -0.0134     0.0120
   21  14.4691   19.6519   -0.0194    -0.0131     0.0077
   22   6.2839   20.0558   -0.0233    -0.0110     0.0053
   23   4.1783   20.3385   -0.0198    -0.0127     0.0175
   24   2.0749   19.8437   -0.0210    -0.0103     0.0020
   25  -0.0034   20.3284   -0.0218    -0.0089     0.0104
   26  -2.0942   20.1265   -0.0224    -0.0080     0.0126
   27  -4.2092   19.9548   -0.0217    -0.0051    -0.0151
```

# VI. CONCLUSIONS

## A. DATA ANALYSIS

Comparison of the three-strut mount and centerplate mount results was best achieved by inspection of the last three plots in the previous section. The lift curve, drag polar and pitching moment curve will again be examined in order.

The lift curve data for both runs yields essentially the same lift curve slope. The slope value of 0.072 $\deg^{-1}$ compares favorably with the theoretical value of approximately 0.073 $\deg^{-1}$. The centerplate mount yielded a $C_{L\max}$ of 0.7588 vice 0.7210 for the three-strut mount. Direct comparison of the measured $C_{L\max}$ was not possible because the test Reynolds numbers were less than those on available published data. It is, however, roughly estimated that the $C_{L\max}$ attainable would be on the order of 0.8 and so close agreement is indicated. Possible cause for the centerplate to exhibit a higher $C_{L\max}$ may be attributed to aerodynamically smoothing the wing attach points with modelling clay/tape and removal of the three-strut interference source. Curve fitting the data points for the centerplate case indicates that its curve may fall very slightly below the three-strut curve. This would yield a very small negative $C_L$ intercept for $\alpha = 0$. If the actual trace were lower, a possible cause might be a difference in bullet-fairing attitude with the wing-on adapter.

Inspection of the drag polar illustrated the need for accurate aerodynamic tares. The $C_{D_{min}}$ at $C_L = 0$ for the three-strut mount is 0.0250 compared to 0.0083 for the aerodynamically corrected centerplate coefficient. This is a gross discrepancy, and one which prompted the construction of a mount for which aerodynamic tares could be more easily acquired. Inspection for the drag tare at the corresponding angle of attack for this condition yielded a drag tare coefficient of 0.0094. This compares very favorably with the estimate of 0.0098 calculated in section IV, part F. Comparison of the centerplate $C_D$ value appears favorable with respect to section data corrected for aspect ratio, but again a direct comparison is not obtainable because of $R_N$ mismatch.

The effect of the unfaired aft strut "disappearing" into the floor was exhibited at higher angles of attack. For each increasingly higher angle of attack condition, the values of the respective $C_D$'s approached each other. The uncompensated contribution of the faired struts became small by comparison to the large $C_D$ measured, and the wetted area of the aft strut was reduced. When $C_L$ is plotted vs. $C_D$, this effect showed up as a tendency toward vertical stacking of the data points from both cases at the higher $C_L$'s.

Finally, inspection of the pitching moment curve reveals several notable discrepancies for the three-strut case, run 051501. The pronounced slope of the linear range indicates that the quarter chord point is aft of the actual aerodynamic

center location. Cause for this would be the detail accuracy required for a chord of 0.5 feet. An error of only a few hundredths of an inch readily shows up. The displacement of the curve to the right indicates the uncorrected interference effects of the three-strut mount, and possibly to a lesser extent, unavoidable limits on airfoil uniformity at this small scale. The airfoil is nominally accurate in contour to 0.001 inches to the quarter chord point and to 0.003 inches thereafter. The centerplate plot of run 052703 showed that marked improvement was available with aerodynamic tares. The relatively large scatter exhibited by the data points was attributed to the small scale and working close to the limits of the balance resolution.

Possible biasing was also noted for the centerplate pitching moment case, in that the repeatability check points predominantly fall to the right for each Q tested. Attempts at localizing this within the data were not conclusive, and the need for additional data points would be indicated for work in which a precise pitching moment was required. Resolution of $C_{M\bar{c}/4}$ inferred by the 27 data points of the presented runs is on the order of 0.005. The pitching moment curve for the centerplate mount does, however, show a considerable improvement over the three-strut mount in that it falls much closer to zero for its constant range. Also, the slope of the faired curve appeared more nearly vertical, indicating a better coincidence of the quarter-chord point with the wing

aerodynamic center. The scatter of the data points somewhat tempered this last observation. A possible fix for the scatter may involve a change of the drag-moment strain gauges on the modified balance to improve the conditioning of the reduction matrix as mentioned by Concannon in Ref. 1, pg. 59.

Summarizing, the centerplate mount has demonstrated a large improvement by incorporating readily attainable aerodynamic tares. The proof of concept experiment displayed excellent agreement with theoretical lift curve slope and indicated "predictable" tendencies for the drag polar and pitching moment curves. Mount flexibility was exhibited by readily adapting an existing calibration wing. The accuracy improvement available with centerplate mounting, coupled with an excellent data system and wall correction program, represents a powerful tool for academic endeavors and independent research on airframe configurations.

## B. RECOMMENDATIONS

The single most disturbing hardware problem involved in the study was the scatter of the data points for the pitching moment coefficient. While this parameter is among the hardest to accurately measure in a small wind tunnel, it is felt that the additional effort to change strain gauges may be warranted if tunnel utilization improves. The current resolution would suffice for any academic use, but the uncertainty may be too great for some engineering work requiring a very precise pitching moment coefficient.

The longest current delay in data reduction is the task of manually reentering all the raw data into the department's HP9830 computer for reduction. The microprocessor data acquisition system does have the capability for instant data reduction but at the loss of the raw data. It also has a punched paper tape output capability. It is felt that the raw data should be retained for system analysis and trouble shooting, but that some additional effort be invested toward interfacing the punched paper tape as a direct input to a software reduction program in one of the available, digital computers.

Further work remains to obtain more complete and current tunnel calibrations including pressure distributions and flow inclinations. It is also recommended that future studies in the tunnel include methods of Reynolds number compensation such as boundary layer tripping, since restricted Reynolds number capability is an inherent tunnel limitation.

Finally, it is felt that this study has contributed to the practicality of the tunnel and that the Department of Aeronautics will see greater utilization of this facility. It is hoped that the advances in modern tunnel research and improved capabilities of this tunnel recommend themselves for a larger share of the Department's curricula and research.

# APPENDIX A

## BASIC AERODYNAMIC AND TUNNEL RELATIONS

A raw data row consists of geometric angle of attack, dynamic pressure, and three strain gauge outputs that have been numerically averaged during a two second sampling interval. The first strain gauge output is directly proportional to lift. Configuration of the balance mixes the drag and moment, consequently, the remaining two strain gauges outputs must be resolved by a calibration matrix. The elements were determined by static loadings and correlation. The calibration matrix to convert gauges outputs in volts D.C. to lift drag and moment force in lbs. was:

$$\left\{ \begin{matrix} L \\ D \\ M \end{matrix} \right\} = \begin{bmatrix} -96.154 & 0 & 0 \\ 0 & 17.500 & 25.575 \\ 0 & -89.065 & -66.070 \end{bmatrix} \left\{ \begin{matrix} L_1 \\ L_2 \\ L_3 \end{matrix} \right\}$$

The coefficients generated by the reduction programs are the non-dimensional coefficients $C_L$, $C_D$, and $C_{M\bar{c}/4}$ given by the relations:

$$C_L = L/QS$$

$$C_D = D/QS$$

$$C_{M\bar{c}/4} = M\bar{c}/4/QS\bar{c}$$

$L_1$ -.0104 0 0

$L_2$ 0 -.0529 -.0[illegible]

$L_3$ 0 .0194 .01[illegible]

$C_L$ was assumed as the independent variable and was only corrected for aerodynamic tares. Geometric angle of attack, and drag were corrected for wall corrections and aerodynamic tares. All data was corrected for wind-off dead weight zero readings and therefore, only the differential readings due to aerodynamic loading were reduced.

Wall corrections take the following form of those on pg. 341, 343 of Ref. 4:

$$\alpha_{aero} = \alpha_{geom} + \Delta\alpha$$

Where $\Delta\alpha = \frac{S}{C} 57.3\ C_L = 0.6102\ C_L$ deg.

$$C_D = C_{Du} + \Delta C_D$$

Where $\Delta C_D = \delta \frac{S}{C} {C_L}^2 = 0.0106\ {C_L}^2$

S = Wing area, 1.5 $ft^2$

C = Tunnel cross-sectional area, 14.5 $ft^2$

$\delta$ = Tunnel factor given by Pope on pg. 343 of Ref. 2,

= 0.103 for the 3.5 x 5.0 octagonal configuration

$\Delta C_M$ was not utilized since the test was wing alone.

No tares other than dead weight were available for the three-strut mount. Wing-off runs were obtained to provide aerodynamic tares for the centerplate mount support situation.

# APPENDIX B

## MOUNT TRANSFER EQUATIONS

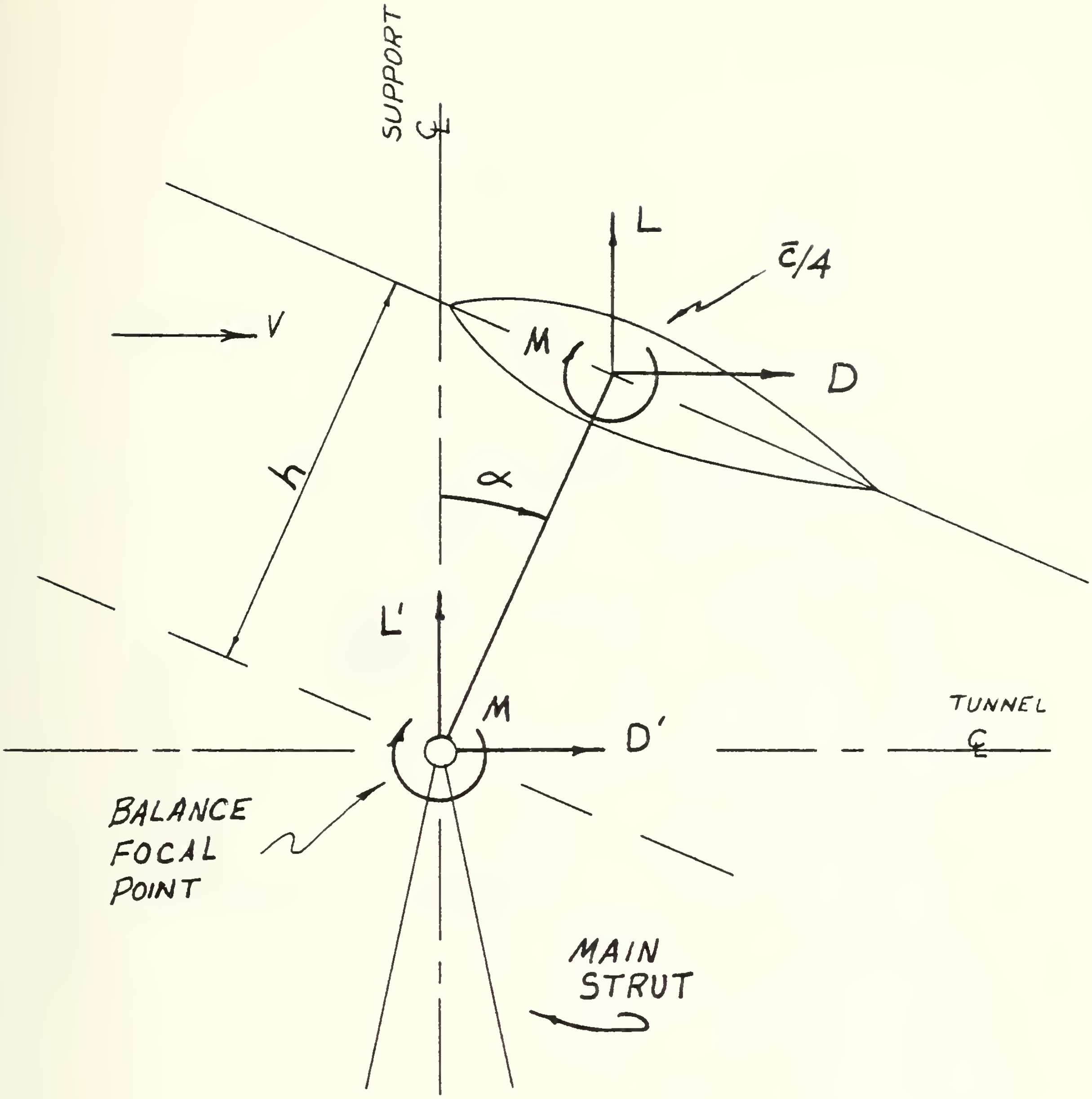
The focal line about which the three component balance resolves lift, drag and moment is centered 25.500 inches above the main beam and on the centerline of the tunnel test section. The three-strut mount wing trunnions are coincident with this axis and as long as the wing A.C. was also coincident no further corrections would be necessary. Plans of the calibration wing indicate that the A.C. was one-tenth inch above the focal axis at zero model angle when on the three-strut mount. The simple moment transfer resulted and the relation can be seen in figure 19.

$$C_M = C_M{}' - \frac{h}{\bar{c}} \cos\alpha \; C_D + \frac{h}{\bar{c}} \sin\alpha \; C_L$$

The main trunnion of the centerplate mount is necessarily below this focal axis and so the aerodynamic forces must be transferred from the model to the focal axis. This relation is slightly different since the pivot axis is not coincident with the focal axis. Also, the wing is located above the upper surface of the centerplate. The equation follows and the relation may be seen on figure 20.

$$C_M = C_M{}' + (h \sin\alpha \; C_L + (1.1667 - h \cos\alpha)C_D)/\bar{c}$$

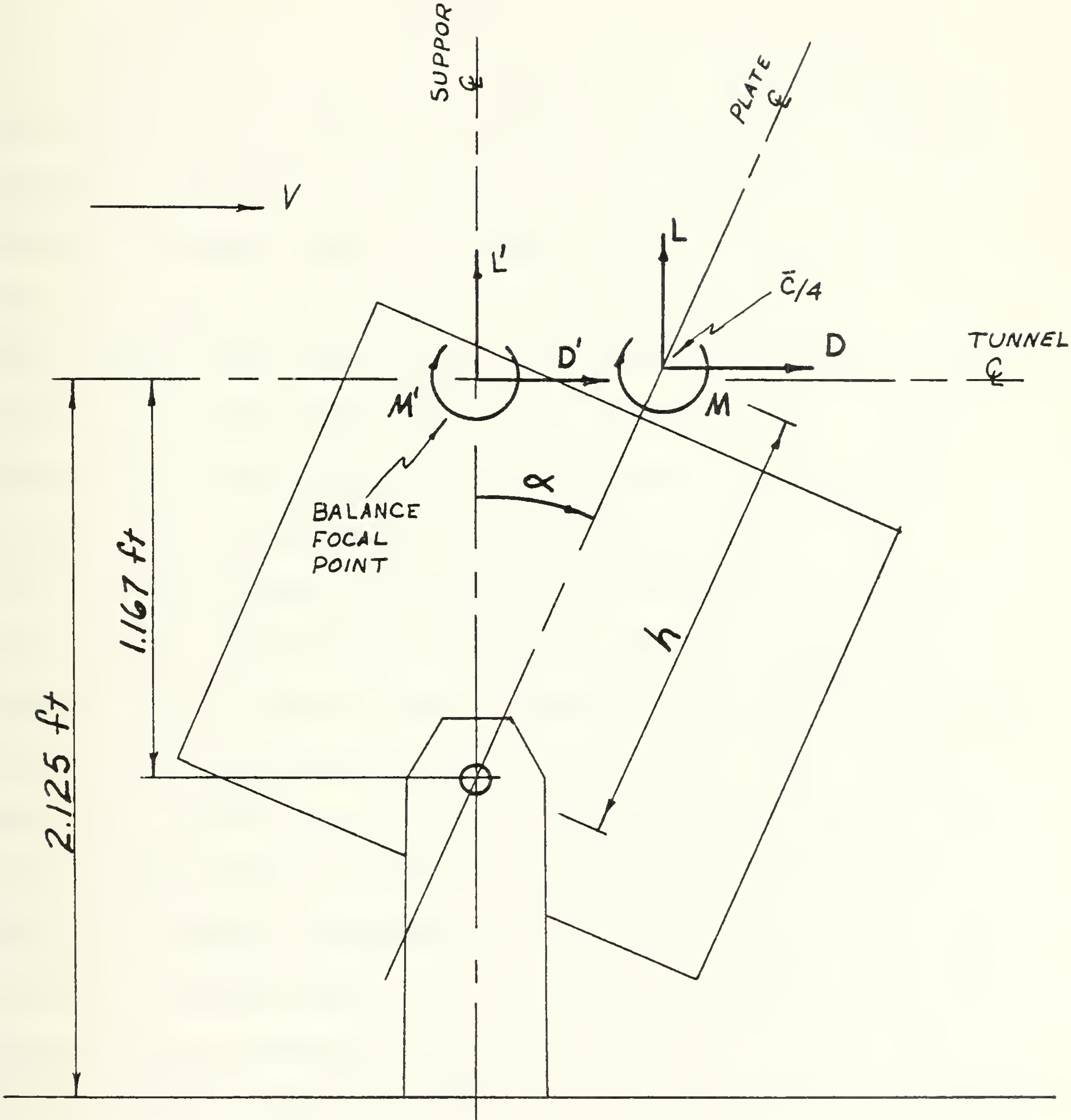
Note that the above equations are in non-dimensional form and those on the figures were in dimensional form for the purpose of clarity. Dividing the figure equations by $QS\bar{c}$ would yield equivalent non-dimensional relations.



$L = L'$ $D = D'$

$$M = M' - hD\cos\alpha + hL\sin\alpha$$

Figure 19. Three-strut moment transfer relations.



$$L = L' \qquad D = D'$$

$$M = M' + hL\sin\alpha + (1.167 - h\cos\alpha)D$$

Figure 20. Centerplate moment transfer relations.

# APPENDIX C

The following data was logged with a new microprocessor data acquisition system. The data variations in format and sequence represent a learning curve as familiarity with the system increased. Each run consists of a minimum of two wind-off zeros and 27 angle of attack conditions. Initial dead weight tares were taken at 21 conditions and two zero checks, but were later expanded to encompass the six extra check point conditions for fully redundant repeatability checks. The initial and final wind-off zeros for runs on the 18th of May were included in the calculation of each run's data. Thereafter, individual wind-off zeros were taken with each run or were repeated as the final and initial data rows in consecutive runs. Initial and final wind-on data rows for the runs of the 27th of May were checked for consistency and then dropped from reduction as the zero point was already redundant within the 27 reduced data rows. In initial weight tare runs for which the precise angle of attack was not required, the angle of attack values were rounded to the nearest integer to speed data entry. Slight deviation between raw data and computer storage values only reflects HP9830 computer rounding for fixed -4 format and not the stored value.

Wind-on to wind-off times for the 27 angle of attack positions settled to about eight minutes with manual angle of attack settings. Programmed microprocessor setting promises to reduce this interval by a factor of one half.

The computer file record of each data group immediately follows the respective raw data.

## TABLE XII

```
RUN NO: 051501 .. 15 MAY 1977
      3 STRUT SUPPORT CALIB. WING


READY
SCAN

 #       CH. 0         CH. 1          CH. 2          CH. 3          CH. 4

030  -.6007         4.397          .5125          6.794E-02      .4039
031  -.4986         4.427          .4633          8.827E-02      .3751
032  -.3979         4.405          .4093          .1054          .3544
033  -.2978         4.358          .3591          .1195          .3329
034  -.1966         4.461          .3135          .1262          .3262
035  -9.753E-02     4.507          .2613          .1303          .3189
036   1.213E-03     4.470          .2111          .1340          .3142
037   .1016         4.427          .1585          .1348          .3125
038   .1970         4.474          .1135          .1321          .3161
039   .2990         4.510          6.167E-02      .1264          .3235
040   .4006         4.548          1.196E-02      .1169          .3347
041   .4994         4.583         -3.835E-02      .1047          .3528
042   .6012         4.530         -8.222E-02      8.964E-02      .3727
043   .7029         4.568         -.1358          7.084E-02      .3989
044   .8017         4.560         -.1777          3.720E-02      .4443
045   .8985         4.492         -.2082         -1.807E-02      .5228
046   .9999         4.461         -.2343         -.1020          .6419
047   1.104         4.381         -.2438         -.1905          .7706
048   1.207         4.370         -.2503         -.2829          .9039
049   1.301         4.400         -.2479         -.3637          1.021
050   1.400         4.291         -.2285         -.4160          1.098
051   .6013         4.485         -7.762E-02      9.221E-02      .3690
052   .3977         4.391          2.206E-02      .1200          .3316
053   .2003         4.402          .1144          .1340          .3130
054   8.343E-03     4.353          .2119          .1366          .3110
055  -.1984         4.197          .3090          .1319          .3164
056  -.3946         4.258          .4065          .1113          .3466
057   1.223E-03    -7.123E-03      .2062          .2029          .2051
058
```

## TABLE XIII

```
RUN NO:   51501

ROW #       CH0          CH1          CH2          CH3          CH4
    1    0.0007       0.0006       0.2071       0.2035       0.2053
    2   -0.6007       4.3970       0.5125       0.0679       0.4039
    3   -0.4986       4.4270       0.4633       0.0883       0.3751
    4   -0.3979       4.4050       0.4093       0.1054       0.3544
    5   -0.2978       4.3580       0.3591       0.1195       0.3329
    6   -0.1966       4.4610       0.3135       0.1262       0.3262
    7   -0.0975       4.5070       0.2613       0.1303       0.3189
    8    0.0012       4.4700       0.2111       0.1340       0.3142
    9    0.1016       4.4270       0.1585       0.1348       0.3125
   10    0.1970       4.4740       0.1135       0.1321       0.3161
   11    0.2990       4.5100       0.0617       0.1264       0.3235
   12    0.4006       4.5480       0.0120       0.1169       0.3347
   13    0.4994       4.5830      -0.0384       0.1047       0.3528
   14    0.6012       4.5300      -0.0822       0.0896       0.3727
   15    0.7029       4.5680      -0.1358       0.0708       0.3989
   16    0.8017       4.5600      -0.1777       0.0372       0.4443
   17    0.8985       4.4920      -0.2082      -0.0181       0.5228
   18    0.9999       4.4610      -0.2343      -0.1020       0.6419
   19    1.1040       4.3810      -0.2438      -0.1905       0.7706
   20    1.2070       4.3700      -0.2503      -0.2829       0.9039
   21    1.3010       4.4000      -0.2479      -0.3637       1.0210
   22    1.4000       4.2910      -0.2285      -0.4160       1.0980
   23    0.6013       4.4850      -0.0776       0.0922       0.3690
   24    0.3977       4.3910       0.0221       0.1200       0.3316
   25    0.2003       4.4020       0.1144       0.1340       0.3130
   26    0.0023       4.3530       0.2119       0.1366       0.3110
   27   -0.1984       4.1970       0.3090       0.1319       0.3164
   28   -0.3946       4.2580       0.4065       0.1113       0.3466
   29    0.0012      -0.0071       0.2062       0.2029       0.2051
 RUN # 51501    DATA IS STORED IN FILE# 8
```

# TABLE XIV

```
RUN NO: STATIC CALIB. ... 15 MAY 1977 AT 1605


READY
SCAN

#        CH. 0          CH. 1          CH. 2        CH. 3        CH. 4

006    1.223E-03      1.242E-03      .2049        .2019        .2050
007   -.6034          1.223E-03      .2053        .2018        .2046
008   -.5001          1.232E-03      .2059        .2017        .2064
009   -.4000          1.223E-03      .2048        .2019        .2063
010   -.3018          1.223E-03      .2052        .2020        .2060
011   -.1968          1.223E-03      .2059        .2021        .2056
012   -9.770E-02      1.223E-03      .2056        .2024        .2043
013   -1.495E-03      1.223E-03      .2058        .2028        .2057
014    9.870E-02      1.223E-03      .2064        .2030        .2048
015    .2001          1.223E-03      .2057        .2035        .2067
016    .3019          1.223E-03      .2054        .2039        .2063
017    .4006          1.223E-03      .2059        .2044        .2048
018    .5020          1.223E-03      .2063        .2051        .2061
019    .6039          1.223E-03      .2062        .2058        .2053
020    .7003          1.194E-03      .2063        .2062        .2056
021    .8043          1.194E-03      .2065        .2066        .2035
022    .9034          1.137E-03      .2069        .2073        .2024
023    1.002          1.099E-03      .2067        .2084        .2031
024    1.100          1.070E-03      .2063        .2096        .2020
025    1.203          5.264E-04      .2063        .2104        .2005
026    1.300          7.648E-04      .2064        .2113        .2009
027    1.403          1.450E-04      .2062        .2124        .2005
028    7.362E-04      5.836E-04      .2071        .2035        .2053
029
```

# TABLE XV

```
RUN NO:   51577

ROW  #       CH0          CH1          CH2          CH3          CH4
     1     0.0000       0.5000       0.2049       0.2019       0.2050
     2    -6.0000       0.0000       0.2053       0.2018       0.2046
     3    -5.0000       0.0000       0.2059       0.2017       0.2064
     4    -4.0000       0.0000       0.2048       0.2019       0.2063
     5    -3.0000       0.0000       0.2052       0.2020       0.2060
     6    -2.0000       0.0000       0.2059       0.2021       0.2056
     7    -1.0000       0.0000       0.2056       0.2024       0.2043
     8     0.0000       0.0000       0.2056       0.2028       0.2057
     9     1.0000       0.0000       0.2064       0.2030       0.2048
    10     2.0000       0.0000       0.2057       0.2035       0.2067
    11     3.0000       0.0000       0.2054       0.2039       0.2063
    12     4.0000       0.0000       0.2059       0.2044       0.2046
    13     5.0000       0.0000       0.2063       0.2051       0.2061
    14     6.0000       0.0000       0.2062       0.2058       0.2053
    15     7.0000       0.0000       0.2063       0.2062       0.2056
    16     8.0000       0.0000       0.2065       0.2066       0.2035
    17     9.0000       0.0000       0.2069       0.2073       0.2024
    18    10.0000       0.0000       0.2067       0.2084       0.2031
    19    11.0000       0.0000       0.2063       0.2096       0.2020
    20    12.0000       0.0000       0.2063       0.2104       0.2005
    21    13.0000       0.0000       0.2064       0.2113       0.2009
    22    14.0000       0.0000       0.2062       0.2124       0.2005
    23     6.0000       0.0000       0.2062       0.2058       0.2053
    24     4.0000       0.0000       0.2059       0.2044       0.2048
    25     2.0000       0.0000       0.2057       0.2035       0.2067
    26     0.0000       0.0000       0.2058       0.2028       0.2057
    27    -2.0000       0.0000       0.2059       0.2021       0.2056
    28    -4.0000       0.0000       0.2048       0.2019       0.2063
    29     0.0000       0.0000       0.2071       0.2035       0.2053
RUN # 51577   DATA IS STOPED IN FILE# 7
```

## TABLE XVI

```
RUN  51801,  Q=40  PSF

@
READY
SCAN

 #          CH. 0           CH. 1           CH. 2           CH. 3           CH. 4

037    -.5973          4.392           .5060           6.868E-02       .3980
038    -.4986          4.291           .4536           9.063E-02       .3675
~~039    -.3926          4.379           .4044           .1068           .3463~~
040    -.3979          4.387           .4081           .1065           .3462
041    -.2990          4.243           .3514           .1210           .3262
042    -.1966          4.240           .3044           .1291           .3157
043    -9.740E-02      4.402           .2611           .1319           .3118
044     1.232E-03      4.399           .2077           .1342           .3091
045     .1015          4.387           .1597           .1338           .3092
046     .2002          4.487           .1081           .1307           .3126
047     .3000          4.444           5.973E-02       .1263           .3178
048     .4007          4.481           1.063E-02       .1177           .3302
049     .4994          4.459          -3.304E-02       .1064           .3467
050     .6015          4.471          -8.295E-02       9.153E-02       .3675
051     .7004          4.454          -.1296           7.331E-02       .3906
052     .8007          4.497          -.1739           3.828E-02       .4331
053     .9008          4.451          -.2074          -1.848E-02       .5215
054     1.000          4.465          -.2376          -.1050           .6442
055     1.102          4.438          -.2523          -.1958           .7757
056     1.201          4.457          -.2647          -.2884           .9092
057     1.300          4.353          -.2516          -.3563           1.0[illegible]7
058     1.400          4.339          -.2289          -.4160           1.093
059     .5984          4.422          -7.739E-02       9.221E-02       .3648
060     .4007          4.496           1.222E-02       .1171           .3314
061     .2002          4.411           .1137           .1318           .3116
062     1.223E-03      4.386           .2046           .1341           .3091
063    -.1967          4.255           .3059           .1302           .3143
064    -.3979          4.351           .4101           .1073           .3477
065     1.223E-03      4.329           .2091           .1354           .3071
066
```

# TABLE XVII

```
RUN NO:   51801

ROW #      CH0         CH1         CH2         CH3         CH4
    1    0.0012      0.0013      0.2035      0.2034      0.2034
    2   -0.5973      4.3920      0.5060      0.0687      0.3990
    3   -0.4986      4.2910      0.4536      0.0906      0.3675
    4   -0.3979      4.3870      0.4081      0.1065      0.3462
    5   -0.2990      4.2430      0.3514      0.1210      0.3262
    6   -0.1966      4.2400      0.3044      0.1291      0.3157
    7   -0.0974      4.4020      0.2611      0.1319      0.3118
    8    0.0012      4.3990      0.2077      0.1342      0.3091
    9    0.1015      4.3870      0.1597      0.1338      0.3092
   10    0.2002      4.4870      0.1081      0.1307      0.3126
   11    0.3000      4.4440      0.0597      0.1263      0.3176
   12    0.4007      4.4810      0.0106      0.1177      0.3302
   13    0.4994      4.4590     -0.0336      0.1064      0.3467
   14    0.6015      4.4710     -0.0830      0.0915      0.3675
   15    0.7004      4.4540     -0.1296      0.0733      0.3906
   16    0.8007      4.4970     -0.1739      0.0383      0.4381
   17    0.9008      4.4510     -0.2074     -0.0185      0.5215
   18    1.0000      4.4650     -0.2376     -0.1050      0.6442
   19    1.1020      4.4380     -0.2523     -0.1958      0.7757
   20    1.2010      4.4570     -0.2647     -0.2884      0.9092
   21    1.3000      4.3530     -0.2516     -0.3563      1.0070
   22    1.4000      4.3390     -0.2289     -0.4160      1.0930
   23    0.5984      4.4220     -0.0774      0.0922      0.3648
   24    0.4007      4.4960      0.0122      0.1171      0.3314
   25    0.2002      4.4110      0.1137      0.1318      0.3116
   26    0.0012      4.3860      0.2046      0.1341      0.3091
   27   -0.1967      4.2550      0.3059      0.1302      0.3143
   28   -0.3979      4.3510      0.4101      0.1073      0.3477
   29    0.0012      0.0166      0.2015      0.2021      0.2033
RUN # 51801    DATA IS STORED IN FILE# 10
```

# TABLE XVIII

RUN 51802, Q=30 PSF

```
@
READY
SCAN

 #        CH. 0          CH. 1          CH. 2          CH. 3          CH. 4

067   -.5947          3.242          .4246          .1060          .3440
068   -.4963          3.207          .3883          .1210          .3213
069   -.3978          3.184          .3526          .1345          .3047
070   -.2992          3.238          .3145          .1423          .2938
071   -.1967          3.178          .2754          .1498          .2833
072   -9.757E-02      3.214          .2429          .1529          .2785
073    1.165E-03      3.254          .2075          .1546          .2755
074    .1015          3.182          .1699          .1553          .2747
075    .2002          3.288          .1312          .1525          .2787
076    .2991          3.285          9.801E-02      .1482          .2849
077    .4005          3.289          6.402E-02      .1415          .2934
078    .5008          3.293          2.374E-02      .1330          .3057
079    .5984          3.320         -9.879E-03      .1228          .3207
080    .7005          3.288         -4.445E-02      .1079          .3419
081    .7994          3.256         -7.017E-02      8.226E-02      .3761
082    .9038          3.309         -.1009          3.514E-02      .4397
083    1.003          3.294         -.1202         -2.544E-02      .5317
084    1.099          3.240         -.1308         -8.801E-02      .6225
085    1.201          3.221         -.1322         -.1511          .7141
086    1.298          3.240         -.1326         -.2111          .8002
087    1.400          3.259         -.1259         -.2646          .8783
088    .5982          3.313         -7.171E-03      .1229          .3214
089    .4007          3.272          6.359E-02      .1426          .2939
090    .2002          3.320          .1370          .1519          .2826
091    1.223E-03      3.309          .2078          .1539          .2793
092   -.1966          3.294          .2797          .1490          .2863
093   -.3979          3.260          .3575          .1328          .3072
094
```

# TABLE XIX

```
RUN NO:   51802

ROW  #       CH0          CH1          CH2          CH3          CH4
     1     0.0012       0.0013       0.2035       0.2034       0.2034
     2    -0.5947       3.2420       0.4246       0.1060       0.3440
     3    -0.4963       3.2070       0.3883       0.1210       0.3213
     4    -0.3978       3.1840       0.3526       0.1345       0.3047
     5    -0.2992       3.2380       0.3145       0.1423       0.2938
     6    -0.1967       3.1780       0.2754       0.1498       0.2833
     7    -0.0976       3.2140       0.2429       0.1529       0.2785
     8     0.0012       3.2540       0.2075       0.1546       0.2755
     9     0.1015       3.1820       0.1699       0.1553       0.2747
    10     0.2002       3.2880       0.1312       0.1525       0.2787
    11     0.2991       3.2850       0.0980       0.1482       0.2849
    12     0.4005       3.2890       0.0640       0.1415       0.2934
    13     0.5008       3.2930       0.0237       0.1330       0.3057
    14     0.5984       3.3200      -0.0099       0.1228       0.3207
    15     0.7065       3.2880      -0.0445       0.1079       0.3419
    16     0.7994       3.2560      -0.0702       0.0823       0.3761
    17     0.9038       3.3090      -0.1009       0.0351       0.4397
    18     1.0030       3.2940      -0.1202      -0.0254       0.5317
    19     1.0990       3.2400      -0.1308      -0.0880       0.6225
    20     1.2010       3.2210      -0.1322      -0.1511       0.7141
    21     1.2960       3.2400      -0.1326      -0.2111       0.8002
    22     1.4000       3.2590      -0.1259      -0.2646       0.8783
    23     0.5982       3.3130      -0.0072       0.1229       0.3214
    24     0.4007       3.2720       0.0636       0.1426       0.2939
    25     0.2002       3.3200       0.1370       0.1519       0.2826
    26     0.0012       3.3090       0.2078       0.1539       0.2793
    27    -0.1966       3.2940       0.2797       0.1490       0.2863
    28    -0.3979       3.2600       0.3575       0.1328       0.3072
    29     0.0012       0.0166       0.2015       0.2021       0.2033
RUN # 51802   DATA IS STORED IN FILE# 11
```

# TABLE XX

```
RUN 51803, Q=20 PSF


@
READY
SCAN

#        CH. 0          CH. 1          CH. 2          CH. 3          CH. 4

095   -.5974         2.164          .3586          .1423          .2915
096   -.4962         2.194          .3356          .1503          .2796
097   -.3979         2.230          .3149          .1570          .2719
098   -.2992         2.185          .2861          .1643          .2601
099   -.1966         2.171          .2610          .1693          .2543
000   -9.751E-02     2.213          .2341          .1706          .2522
001    1.223E-03     2.221          .2096          .1715          .2522
002    9.852E-02     2.230          .1850          .1711          .2516
003    .1997         2.239          .1568          .1700          .2524
004    .2991         2.217          .1341          .1672          .2559
005    .3992         2.231          .1105          .1624          .2618
006    .4994         2.255          8.094E-02      .1569          .2710
007    .6014         2.217          6.025E-02      .1503          .2793
008    .7003         2.263          3.254E-02      .1381          .2961
009    .8018         2.214          1.452E-02      .1196          .3208
010    .9005         2.244          6.504E-04      9.240E-02      .3573
011    1.0000         2.254         -1.678E-02      4.410E-02      .4272
012    1.100          2.186         -1.699E-02      4.942E-03      .4857
013    1.201          2.201         -2.224E-02     -3.561E-02      .5487
014    1.301          2.200         -2.173E-02     -7.521E-02      .6077
015    1.400          2.208         -1.462E-02     -.1074          .6547
016    .6015         2.239          5.906E-02      .1505          .2801
017    .4005         2.219          .1076          .1642          .2603
018    .2001         2.228          .1617          .1699          .2530
019    1.223E-03     2.208          .2107          .1721          .2506
020   -.1965         2.228          .2632          .1686          .2558
021   -.3978         2.183          .3136          .1579          .2696
022    1.223E-03     1.639E-02      .2017          .2013          .2027
023



       1.223E-03     1.662E-02      .2015          .2021          .2033
024
```

## TABLE XXI

```
RUN NO:  51803

ROW #      CH0          CH1          CH2          CH3          CH4
    1    0.0012       0.0013       0.2035       0.2034       0.2034
    2   -0.5974       2.1640       0.3586       0.1423       0.2915
    3   -0.4962       2.1940       0.3356       0.1503       0.2796
    4   -0.3979       2.2300       0.3149       0.1570       0.2719
    5   -0.2992       2.1850       0.2861       0.1643       0.2601
    6   -0.1966       2.1710       0.2610       0.1693       0.2543
    7   -0.0975       2.2130       0.2341       0.1706       0.2522
    8    0.0012       2.2210       0.2096       0.1715       0.2522
    9    0.0985       2.2300       0.1850       0.1711       0.2516
   10    0.1997       2.2390       0.1568       0.1700       0.2524
   11    0.2991       2.2170       0.1341       0.1672       0.2559
   12    0.3992       2.2310       0.1105       0.1624       0.2618
   13    0.4994       2.2550       0.0809       0.1569       0.2710
   14    0.6014       2.2170       0.0603       0.1503       0.2793
   15    0.7003       2.2630       0.0325       0.1381       0.2961
   16    0.8018       2.2140       0.0145       0.1196       0.3208
   17    0.9005       2.2440       0.0007       0.0924       0.3573
   18    1.0000       2.2540      -0.0168       0.0441       0.4272
   19    1.1000       2.1860      -0.0170       0.0049       0.4857
   20    1.2010       2.2010      -0.0222      -0.0356       0.5487
   21    1.3010       2.2000      -0.0217      -0.0752       0.6077
   22    1.4000       2.2080      -0.0146      -0.1074       0.6547
   23    0.6015       2.2390       0.0591       0.1505       0.2801
   24    0.4005       2.2190       0.1076       0.1642       0.2603
   25    0.2001       2.2280       0.1617       0.1699       0.2530
   26    0.0012       2.2080       0.2107       0.1721       0.2506
   27   -0.1965       2.2280       0.2632       0.1686       0.2558
   28   -0.3978       2.1830       0.3136       0.1579       0.2696
   29    0.0012       0.0166       0.2015       0.2021       0.2033
RUN # 51803   DATA IS STORED IN FILE# 12
```

## TABLE XXII

18 MAY 1977   WIND OFF BALANCE READINGS 1500

```
)@
READY
SCAN

 #        CH. 0          CH. 1          CH. 2          CH. 3          CH. 4

006    1.223E-03      1.223E-03      .2010          .2019          .2032
007   -.6006          1.223E-03      .2014          .2015          .2038
008   -.4986          1.223E-03      .2012          .2015          .2034
009   -.3997          1.223E-03      .2014          .2017          .2041
010   -.2987          1.223E-03      .2016          .2016          .2054
011   -.1995          1.223E-03      .2019          .2020          .2034
012   -9.728E-02      1.232E-03      .2022          .2023          .2042
013    1.223E-03      1.223E-03      .2026          .2028          .2031
014    .1016          1.223E-03      .2019          .2029          .2030
015    .2001          1.232E-03      .2019          .2035          .2020
016    .2992          1.242E-03      .2030          .2042          .2025
017    .4007          1.223E-03      .2021          .2045          .2022
018    .4994          1.223E-03      .2030          .2052          .2017
019    .6021          1.270E-03      .2032          .2059          .2024
020    .7003          1.280E-03      .2025          .2062          .2017
021    .7998          1.242E-03      .2028          .2068          .2005
022    .9009          1.280E-03      .2033          .2077          .2001
023    1.000          1.261E-03      .2026          .2086          .2007
024    1.100          1.251E-03      .2030          .2095          .1990
025    1.201          1.404E-03      .2035          .2107          .1977
026    1.300          1.299E-03      .2023          .2113          .1979
027    1.400          1.308E-03      .2028          .2124          .1964
028    .5982          1.289E-03      .2034          .2059          .2011
~~029    .3698          1.337E-03      .2034          .2048          .2021~~
030    .4006          1.337E-03      .2031          .2048          .2020
031    .2001          1.337E-03      .2027          .2039          .2023
032    1.223E-03      1.299E-03      .2029          .2033          .2027
033   -.1967          1.337E-03      .2024          .2025          .2025
034   -.3977          1.537E-03      .2017          .2027          .2030
035    1.232E-03      1.308E-03      .2035          .2034          .2034
036
```

# TABLE XXIII

```
RUN NO:   51877

ROW  #      CH0          CH1          CH2          CH3          CH4
     1    0.0000       0.0000       0.2010       0.2019       0.2032
     2   -6.0000       0.0000       0.2014       0.2015       0.2038
     3   -5.0000       0.0000       0.2012       0.2015       0.2034
     4   -4.0000       0.0000       0.2014       0.2017       0.2041
     5   -3.0000       0.0000       0.2016       0.2016       0.2054
     6   -2.0000       0.0000       0.2019       0.2020       0.2034
     7   -1.0000       0.0000       0.2022       0.2023       0.2042
     8    0.0000       0.0000       0.2026       0.2028       0.2031
     9    1.0000       0.0000       0.2019       0.2029       0.2030
    10    2.0000       0.0000       0.2019       0.2035       0.2020
    11    3.0000       0.0000       0.2030       0.2042       0.2025
    12    4.0000       0.0000       0.2021       0.2045       0.2022
    13    5.0000       0.0000       0.2030       0.2052       0.2017
    14    6.0000       0.0000       0.2032       0.2059       0.2024
    15    7.0000       0.0000       0.2025       0.2062       0.2017
    16    8.0000       0.0000       0.2028       0.2068       0.2005
    17    9.0000       0.0000       0.2033       0.2077       0.2001
    18   10.0000       0.0000       0.2026       0.2086       0.2007
    19   11.0000       0.0000       0.2030       0.2095       0.1190
    20   12.0000       0.0000       0.2035       0.2107       0.1977
    21   13.0000       0.0000       0.2023       0.2113       0.1979
    22   14.0000       0.0000       0.2028       0.2124       0.1964
    23    6.0000       0.0000       0.2034       0.2059       0.2011
    24    4.0000       0.0000       0.2031       0.2048       0.2020
    25    2.0000       0.0000       0.2027       0.2039       0.2023
    26    0.0000       0.0000       0.2029       0.2033       0.2027
    27   -2.0000       0.0000       0.2024       0.2025       0.2025
    28   -4.0000       0.0000       0.2017       0.2027       0.2030
    29    0.0000       0.0000       0.2035       0.2034       0.2034
RUN # 51877   DATA IS STORED IN FILE# 9
```

# TABLE XXIV

```
RUN 052602  ON 26 MAY 1977
PLATE PLUS FAIRING (WING OFF)
NOMINAL Q= 40 PSF


@
> SCAN

 #-     CH. 0     CH. 1     CH. 2     CH. 3     CH. 4

064     .0122     .0158     .0079     .0042     .0012
065     .0122     4.475    -.0024    -.0239     .0418
066    -5.971     4.467    -.0026     .0014     .0218
067    -4.982     4.441    -.0030    -.0004     .0268
068    -3.973     4.480    -.0011    -.0054     .0311
069    -2.979     4.396    -.0018    -.0098     .0330
070    -1.989     4.410    -.0022    -.0145     .0360
071    -.9666      4.353    -.0037    -.0194     .0380
072     .0122     4.438    -.0045    -.0251     .0419
073     .9912     4.373    -.0042    -.0290     .0458
074     2.005     4.383    -.0044    -.0334     .0465
075     2.994     4.441    -.0031    -.0379     .0517
076     4.001     4.411    -.0035    -.0422     .0544
077     4.999     4.409    -.0046    -.0456     .0562
078     5.990     4.398    -.0050    -.0498     .0593
079     6.984     4.383    -.0062    -.0539     .0624
080     7.998     4.380    -.0059    -.0572     .0641
081     9.001     4.322    -.0064    -.0607     .0670
082     10.01     4.447    -.0063    -.0656     .0719
083     11.00     4.408    -.0073    -.0690     .0736
084     11.99     4.381    -.0079    -.0729     .0771
085     12.99     4.357    -.0078    -.0764     .0800
086     13.98     4.373    -.0082    -.0800     .0[illegible]
087     5.990     4.402    -.0042    -.0493     .0593
088     3.984     4.398    -.0034    -.0411     .0535
089     1.977     4.343    -.0023    -.0324     .0469
090     .0122     4.427    -.0018    -.0233     .0419
091    -1.988     4.344    -.0017    -.0132     .0337
092    -3.970     4.367    -.0013    -.0046     .0279
093     .0122     4.346    -.0016    -.0234     .0412
094     .0122     .0203     .0065     .0020     .0012
```

## TABLE XXV

```
RUN NO:   52602

ROW  #      CH0          CH1          CH2          CH3          CH4
     1    0.0122       0.0158       0.0079       0 0042       0.0012
     2   -5.9710       4.4670      -0.0026       0.0014       0.0218
     3   -4.9820       4.4410      -0.0030      -0.0004       0.0268
     4   -3.9730       4.4800      -0.0011      -0.0054       0.0311
     5   -2.9790       4.3960      -0.0018      -0.0098       0.0330
     6   -1.9890       4.4100      -0.0022      -0.0145       0.0360
     7   -0.9666       4.3530      -0.0037      -0.0194       0.0380
     8    0.0122       4.4380      -0.0045      -0.0251       0.0419
     9    0.9912       4.3730      -0.0042      -0.0290       0.0458
    10    2.0050       4.3830      -0.0044      -0.0334       0.0465
    11    2.9940       4.4410      -0.0031      -0.0379       0.0517
    12    4.0010       4.4110      -0.0035      -0.0422       0.0544
    13    4.9990       4.4090      -0.0046      -0.0456       0.0562
    14    5.9900       4.3980      -0.0050      -0.0498       0.0593
    15    6.9840       4.3830      -0.0062      -0.0539       0.0624
    16    7.9980       4.3800      -0.0059      -0.0572       0.0641
    17    9.0010       4.3220      -0.0064      -0.0607       0.0670
    18   10.0100       4.4470      -0.0063      -0.0656       0.0719
    19   11.0000       4.4080      -0.0073      -0.0690       0.0736
    20   11.9900       4.3810      -0.0079      -0.0729       0.0771
    21   12.9900       4.3570      -0.0078      -0.0764       0.0800
    22   13.9800       4.3730      -0.0082      -0.0800       0.0835
    23    5.9900       4.4020      -0.0042      -0.0493       0.0593
    24    3.9840       4.3980      -0.0034      -0.0411       0.0535
    25    1.9770       4.3430      -0.0023      -0.0324       0.0469
    26    0.0122       4.4270      -0.0018      -0.0233       0.0419
    27   -1.9880       4.3440      -0.0017      -0.0132       0.0337
    28   -3.9700       4.3670      -0.0013      -0.0046       0.0279
    29    0.0122       0.0203       0.0065       0.0020       0.0012
RUN # 52602   DATA IS STORED IN FILE# 5
```

# TABLE XXVI

```
RUN 052603  ON 26 MAY 1977
PLATE PLUS FAIRING (WING OFF)
NOMINAL Q= 30 PSF


@
> SCAN

 #      CH. 0     CH. 1     CH. 2     CH. 3     CH. 4

095     .0122     .0187     .0056     .0012     .0012
096     .0122     3.249    -.0006    -.0184     .0316
097    -5.968     3.228    -.0009     .0035     .0133
098    -4.981     3.283    -.0016     .0012     .0173
099    -3.983     3.210    -.0009    -.0007     .0202
100    -2.979     3.263    -.0002    -.0059     .0235
101    -1.984     3.282    -.0014    -.0102     .0253
102    -.9658     3.236    -.0010    -.0146     .0297
103     .0122     3.287    -.0004    -.0186     .0321
104     .9927     3.325    -.0005    -.0242     .0353
105     2.011     3.244     .0005    -.0275     .0369
106     2.999     3.241    -.0009    -.0311     .0401
107     3.988     3.198    -.0010    -.0353     .0428
108     5.002     3.272    -.0017    -.0391     .0467
109     5.994     3.246    -.0015    -.0427     .0484
110     6.988     3.224    -.0014    -.0463     .0513
111     8.002     3.235    -.0026    -.0507     .0550
112     8.997     3.214    -.0030    -.0545     .0578
113     10.01     3.281    -.0033    -.0585     .0610
114     11.00     3.302    -.0040    -.0625     .0632
115     12.00     3.234    -.0045    -.0661     .0656
116     13.00     3.300    -.0047    -.0702     .0689
117     13.98     3.209    -.0059    -.0734     .0703
118     5.994     3.236    -.0015    -.0435     .0491
119     3.988     3.197    -.0004    -.0359     .0425
120     1.982     3.245    -.0004    -.0278     .0369
121     .0122     3.252    -.0009    -.0185     .0318
122    -1.984     3.273     .0002    -.0104     .0258
123    -3.992     3.269     .0004    -.0011     .0199
124     .0122     3.204    -.0012    -.0186     .0309
125     .0122     .0211     .0054     .0012     .0012
```

# TABLE XXVII

```
RUN NO:   52603

ROW #      CH0         CH1         CH2         CH3         CH4
    1    0.0122      0.0187      0.0056      0.0012      0.0012
    2   -5.9680      3.2280     -0.0009      0.0035      0.0133
    3   -4.9810      3.2830     -0.0016      0.0012      0.0173
    4   -3.9830      3.2100     -0.0009     -0.0007      0.0202
    5   -2.9790      3.2630     -0.0002     -0.0059      0.0235
    6   -1.9840      3.2820     -0.0014     -0.0102      0.0253
    7   -0.9658      3.2360     -0.0010     -0.0146      0.0297
    8    0.0122      3.2870     -0.0004     -0.0186      0.0321
    9    0.9927      3.3250     -0.0005     -0.0242      0.0353
   10    2.0110      3.2440      0.0005     -0.0275      0.0369
   11    2.9990      3.2410     -0.0009     -0.0311      0.0401
   12    3.9880      3.1980     -0.0010     -0.0353      0.0428
   13    5.0020      3.2720     -0.0017     -0.0391      0.0467
   14    5.9940      3.2460     -0.0015     -0.0427      0.0484
   15    6.9880      3.2240     -0.0014     -0.0463      0.0513
   16    8.0020      3.2350     -0.0026     -0.0507      0.0550
   17    8.9970      3.2140     -0.0030     -0.0545      0.0578
   18   10.0100      3.2810     -0.0033     -0.0585      0.0610
   19   11.0000      3.3020     -0.0040     -0.0625      0.0632
   20   12.0000      3.2340     -0.0045     -0.0661      0.0656
   21   13.0000      3.3000     -0.0047     -0.0702      0.0689
   22   13.9800      3.2090     -0.0059     -0.0734      0.0703
   23    5.9940      3.2360     -0.0015     -0.0435      0.0491
   24    3.9880      3.1970     -0.0004     -0.0359      0.0425
   25    1.9920      3.2450     -0.0004     -0.0278      0.0369
   26    0.0122      3.2520     -0.0009     -0.0185      0.0318
   27   -1.9840      3.2730      0.0002     -0.0104      0.0258
   28   -3.9920      3.2690      0.0004     -0.0011      0.0199
   29    0.0122      0.0211      0.0054      0.0012      0.0012
RUN # 52603   DATA IS STORED IN FILE# 6
```

# TABLE XXVIII

```
RUN 052601  ON 26 MAY 1977
PLATE PLUS FAIRING (WING OFF)
NOMINAL Q= 20 PSF

@@
> SCAN

 #     CH. 0    CH. 1    CH. 2    CH. 3    CH. 4

033    .0122    .0124    .0067    .0024    .0012
034    .0122    2.175    .0012   -.0104    .0199
035   -5.974    2.176    .0012    .0115    .0030
036   -4.984    2.192    .0013    .0076    .0050
037   -3.995    2.207    .0013    .0031    .0090
038   -2.982    2.186    .0012    .0012    .0112
039   -1.992    2.175    .0016    .0000    .0142
040   -.9688    2.184    .0014   -.0048    .0176
041    .0122    2.187    .0012   -.0091    .0206
042    .9910    2.167    .0016   -.0123    .0233
043    2.006    2.154    .0015   -.0168    .0277
044    2.994    2.191    .0019   -.0199    .0312
045    3.984    2.171    .0029   -.0238    .0338
046    4.998    2.194    .0021   -.0277    .0354
047    5.990    2.142    .0016   -.0308    .0372
048    6.984    2.184    .0018   -.0349    .0390
049    7.998    2.152    .0021   -.0378    .0410
050    9.002    2.163    .0013   -.0415    .0442
051    10.01    2.182    .0016   -.0452    .0457
052    10.99    2.178    .0014   -.0484    .0486
053    12.00    2.165    .0014   -.0517    .0507
054    12.99    2.162    .0013   -.0556    .0545
055    13.98    2.195    .0012   -.0585    .0564
056    5.991    2.189    .0015   -.0311    .0365
057    3.985    2.149    .0022   -.0231    .0323
058    1.977    2.163    .0020   -.0157    .0266
059    .0122    2.174    .0021   -.0080    .0202
060   -1.989    2.213    .0018    .0011    .0132
061   -3.993    2.188    .0017    .0047    .0079
062    .0122    2.176    .0018   -.0081    .0209
063    .0122    .0164    .0076    .0043    .0012
```

# TABLE XXIX

```
RUN NO:   52601

ROW  #      CH0          CH1          CH2          CH3          CH4
     1    0.0122       0.0124       0.0067       0.0024       0.0012
     2   -5.9740       2.1760       0.0012       0.0115       0.0030
     3   -4.9840       2.1920       0.0013       0.0076       0.0050
     4   -3.9950       2.2070       0.0013       0.0031       0.0090
     5   -2.9820       2.1860       0.0012       0.0012       0.0112
     6   -1.9920       2.1750       0.0016       0.0000       0.0142
     7   -0.9688       2.1840       0.0014      -0.0048       0.0176
     8    0.0122       2.1870       0.0012      -0.0091       0.0206
     9    0.9910       2.1670       0.0016      -0.0123       0.0233
    10    2.0060       2.1540       0.0015      -0.0168       0.0277
    11    2.9940       2.1910       0.0019      -0.0199       0.0312
    12    3.9840       2.1710       0.0029      -0.0238       0.0338
    13    4.9980       2.1940       0.0021      -0.0277       0.0354
    14    5.9900       2.1420       0.0016      -0.0308       0.0372
    15    6.9840       2.1840       0.0018      -0.0349       0.0390
    16    7.9980       2.1520       0.0021      -0.0378       0.0410
    17    9.0020       2.1630       0.0013      -0.0415       0.0442
    18   10.0100       2.1820       0.0016      -0.0452       0.0457
    19   10.9900       2.1780       0.0014      -0.0484       0.0486
    20   12.0000       2.1650       0.0014      -0.0517       0.0507
    21   12.9900       2.1620       0.0013      -0.0556       0.0545
    22   13.9800       2.1950       0.0012      -0.0585       0.0564
    23    5.9910       2.1890       0.0015      -0.0311       0.0365
    24    3.9850       2.1490       0.0022      -0.0231       0.0323
    25    1.9770       2.1630       0.0020      -0.0157       0.0266
    26    0.0122       2.1740       0.0021      -0.0080       0.0202
    27   -1.9890       2.2130       0.0018       0.0011       0.0132
    28   -3.9930       2.1880       0.0017       0.0047       0.0079
    29    0.0122       0.0164       0.0076       0.0043       0.0012
RUN # 52601    DATA IS STORED IN FILE# 4
```

# TABLE XXX

```
1620 ON 26 MAY 1977
   .. STATIC WEIGHT TARES WIND-OFF..
   .. PLATE PLUS FAIRING (WING-OFF)

@
> SCAN

 #      CH. 0     CH. 1     CH. 2     CH. 3     CH. 4

004     .0122     .0037     .0014     .0012     .0011
005    -5.993     .0035     .0012     .0201    -.0134
006    -4.985     .0048     .0020     .0181    -.0117
007    -3.979     .0059     .0017     .0151    -.0102
008    -2.976     .0064     .0029     .0114    -.0076
009    -1.992     .0065     .0036     .0081    -.0041
010    -1.005     .0066     .0027     .0048    -.0029
011    -.0047     .0061     .0038     .0014     .0010
012     .9893     .0060     .0030     .0012     .0012
013     1.975     .0062     .0041    -.0020     .0014
014     2.983     .0064     .0039    -.0061     .0049
015     3.982     .0067     .0047    -.0088     .0060
016     4.998     .0066     .0030    -.0133     .0090
017     5.988     .0072     .0042    -.0166     .0112
018     6.984     .0079     .0045    -.0183     .0133
019     7.998     .0079     .0049    -.0216     .0150
020     8.991     .0077     .0052    -.0247     .0158
021     9.978     .0083     .0047    -.0278     .0190
022     11.00     .0084     .0050    -.0304     .0201
023     12.01     .0092     .0047    -.0338     .0220
024     12.99     .0093     .0049    -.0366     .0253
025     14.01     .0094     .0047    -.0382     .0264
026     5.986     .0099     .0062    -.0138     .0111
027     3.981     .0100     .0057    -.0073     .0062
028     1.975     .0098     .0059     .0012     .0025
029     .0120     .0101     .0063     .0037     .0012
030    -1.991     .0100     .0063     .0106    -.0034
031    -3.977     .0107     .0059     .0185    -.0081
032     .0122     .0109     .0076     .0043     .0012
```

# TABLE XXXI

```
RUN NO:   52677

ROW #       CH0          CH1          CH2          CH3          CH4
    1    0.0122       0.0037       0.0014       0.0012       0.0011
    2   -5.9930       0.0035       0.0012       0.0201      -0.0134
    3   -4.9850       0.0048       0.0020       0.0181      -0.0117
    4   -3.9790       0.0059       0.0017       0.0151      -0.0102
    5   -2.9760       0.0064       0.0029       0.0114      -0.0076
    6   -1.9920       0.0065       0.0036       0.0081      -0.0041
    7   -1.0050       0.0066       0.0027       0.0048      -0.0029
    8   -0.0047       0.0061       0.0038       0.0014       0.0010
    9    0.9893       0.0060       0.0030       0.0012       0.0012
   10    1.9750       0.0062       0.0041      -0.0020       0.0014
   11    2.9830       0.0064       0.0039      -0.0061       0.0049
   12    3.9820       0.0067       0.0047      -0.0088       0.0060
   13    4.9980       0.0066       0.0030      -0.0133       0.0030
   14    5.9880       0.0072       0.0042      -0.0166       0.0112
   15    6.9840       0.0079       0.0045      -0.0183       0.0133
   16    7.9980       0.0079       0.0049      -0.0216       0.0150
   17    5.9910       0.0077       0.0052      -0.0247       0.0158
   18    9.9780       0.0083       0.0047      -0.0278       0.0190
   19   11.0000       0.0084       0.0050      -0.0304       0.0201
   20   12.0100       0.0092       0.0047      -0.0338       0.0220
   21   12.9900       0.0093       0.0049      -0.0366       0.0253
   22   14.0100       0.0094       0.0047      -0.0382       0.0264
   23    5.9860       0.0099       0.0062      -0.0138       0.0111
   24    3.9810       0.0100       0.0057      -0.0073       0.0062
   25    1.9750       0.0098       0.0059       0.0012       0.0025
   26    0.0120       0.0101       0.0063       0.0037       0.0012
   27   -1.9910       0.0100       0.0063       0.0106      -0.0034
   28   -3.9770       0.0107       0.0059       0.0185      -0.0081
   29    0.0122       0.0109       0.0076       0.0043       0.0012
RUN # 52677   DATA IS STORED IN FILE# 3
```

XXXII

```
RUN 052703    ON 27 MAY 1977
PLATE PLUS FAIRING AND WING
NOMINAL Q= 40 PSF


SC@
> SCNA

 #      CH. 0     CH. 1     CH. 2     CH. 3     CH. 4

092    .0122     .2229     .0052     .0063     .0019
093    .0122     41.02     .0066    -.0462     .0800
094   -5.948     39.55     .3015     .0254     .0649
095   -4.962     39.89     .2561     .0120     .0615
096   -3.962     39.56     .2026     .0005     .0620
097   -2.956     40.23     .1487    -.0134     .0656
098   -1.960     40.13     .1031    -.0234     .0662
099   -.9533     39.97     .0552    -.0353     .0723
100    .0122     40.69     .0079    -.0455     .0798
101    1.015     40.79    -.0392    -.0530     .0839
102    2.002     40.86    -.0925    -.0573     .0905
103    3.022     40.82    -.1424    -.0607     .0978
104    4.010     40.68    -.1872    -.0635     .1075
105    5.026     40.96    -.2393    -.0645     .1175
106    6.016     41.27    -.2892    -.0658     .1320
107    7.010     40.85    -.3339    -.0704     .1533
108    8.022     40.98    -.3756    -.0858     .1891
109    9.013     41.47    -.4239    -.1228     .2630
110    10.03     40.86    -.4517    -.1800     .3664
111    11.02     40.88    -.4762    -.2431     .4788
112    12.02     40.59    -.4874    -.3096     .5928
113    13.01     40.00    -.4844    -.3767     .7027
114    14.01     40.23    -.4834    -.4371     .8013
115    6.018     41.15    -.2862    -.0670     .1341
116    4.011     40.56    -.1875    -.0629     .1084
117    2.017     41.01    -.0894    -.0573     .0920
118    .0122     41.27     .0119    -.0449     .0803
119   -1.961     40.10     .1073    -.0221     .0674
120   -3.978     40.59     .2092     .0006     .0636
121    .0122     40.17     .0089    -.0429     .0792
122    .0122     .2811     .0012     .0057     .0012
```

## TABLE XXXIII

```
RUN NO:   52703

ROW #       CH0          CH1          CH2          CH3          CH4
    1     0.0122      0.2229       0.0052       0.0063      0.0019
    2    -5.9480     39.5500       0.3015       0.0254      0.0649
    3    -4.9620     39.8900       0.2561       0.0120      0.0615
    4    -3.9620     39.5600       0.2026       0.0005      0.0620
    5    -2.9560     40.2300       0.1487      -0.0134      0.0656
    6    -1.9600     40.1300       0.1031      -0.0234      0.0662
    7    -0.9533     39.9700       0.0552      -0.0353      0.0723
    8     0.0122     40.6900       0.0079      -0.0455      0.0798
    9     1.0150     40.7900      -0.0392      -0.0530      0.0839
   10     2.0020     40.8600      -0.0925      -0.0573      0.0905
   11     3.0220     40.8200      -0.1424      -0.0607      0.0978
   12     4.0100     40.6800      -0.1872      -0.0635      0.1075
   13     5.0260     40.9600      -0.2393      -0.0645      0.1175
   14     6.0160     41.2700      -0.2892      -0.0658      0.1320
   15     7.0100     40.8500      -0.3339      -0.0704      0.1533
   16     8.0220     40.9800      -0.3756      -0.0858      0.1891
   17     9.0130     41.4700      -0.4239      -0.1228      0.2630
   18    10.0300     40.8600      -0.4517      -0.1800      0.3664
   19    11.0200     40.8800      -0.4762      -0.2431      0.4788
   20    12.0200     40.5900      -0.4874      -0.3096      0.5928
   21    13.0100     40.0000      -0.4844      -0.3767      0.7027
   22    14.0100     40.2300      -0.4834      -0.4371      0.8013
   23     6.0180     41.1500      -0.2862      -0.0670      0.1341
   24     4.0110     40.5600      -0.1875      -0.0629      0.1084
   25     2.0170     41.0100      -0.0894      -0.0573      0.0920
   26     0.0122     41.2700       0.0119      -0.0449      0.0803
   27    -1.9610     40.1000       0.1073      -0.0221      0.0674
   28    -0.9780     40.5900       0.2092       0.0006      0.0636
   29     0.0122      0.2811       0.0012       0.0057      0.0012
 RUN # 52703   DATA IS STORED IN FILE# 10
```

## TABLE XXXIV

```
RUN 052702   ON 27 MAY 1977
PLATE PLUS FAIRING AND WING
NOMINAL Q= 30 PSF


@
> SCAN

 #      CH. 0     CH. 1     CH. 2     CH. 3     CH. 4

061     .0122     .1835     .0046     .0049     .0012
062     .0122     30.97     .0032    -.0343     .0608
063    -5.948     30.15     .2277     .0270     .0449
064    -4.962     30.89     .1965     .0132     .0468
065    -3.945     30.30     .1549     .0036     .0442
066    -2.955     30.68     .1170    -.0037     .0455
067    -1.960     30.39     .0758    -.0151     .0504
068    -.9538     30.53     .0419    -.0246     .0548
069     .0122     30.73     .0040    -.0343     .0612
070     .9997     30.59    -.0322    -.0402     .0664
071     2.005     30.60    -.0734    -.0451     .0718
072     3.023     30.75    -.1106    -.0516     .0768
073     4.009     30.76    -.1475    -.0540     .0843
074     5.027     30.87    -.1829    -.0569     .0945
075     6.017     30.97    -.2232    -.0573     .1055
076     7.008     30.78    -.2520    -.0639     .1252
077     8.022     30.75    -.2893    -.0808     .1600
078     9.012     30.62    -.3134    -.1083     .2096
079     10.02     30.58    -.3399    -.1531     .2906
080     11.02     30.55    -.3563    -.2017     .3754
081     12.02     30.57    -.3670    -.2554     .4665
082     13.01     30.12    -.3631    -.3036     .5426
083     14.01     30.45    -.3683    -.3531     .6267
084     6.017     30.54    -.2189    -.0563     .1059
085     4.010     30.90    -.1449    -.0522     .0851
086     2.005     30.40    -.0647    -.0458     .0726
087     .0122     30.75     .0052    -.0335     .0619
088    -1.962     30.73     .0821    -.0144     .0513
089    -3.979     30.36     .1579     .0044     .0436
090     .0122     30.11     .0064    -.0326     .0604
091     .0122     .2240     .0038     .0054     .0014
```

# TABLE XXXV

```
RUN NO:   52702

ROW  #     CH0         CH1         CH2         CH3         CH4
     1    0.0122     0.1835     0.0046      0.0049     0.0012
     2   -5.9480    30.1500     0.2277      0.0270     0.0449
     3   -4.9620    30.2900     0.1965      0.0132     0.0468
     4   -3.9450    30.3000     0.1549      0.0036     0.0442
     5   -2.9550    30.6800     0.1170     -0.0037     0.0455
     6   -1.9600    30.3900     0.0758     -0.0151     0.0504
     7   -0.9538    30.5300     0.0419     -0.0246     0.0548
     8    0.0122    30.7300     0.0040     -0.0343     0.0612
     9    0.9997    30.5900    -0.0322     -0.0402     0.0664
    10    2.0050    30.6000    -0.0734     -0.0451     0.0718
    11    3.0230    30.7500    -0.1106     -0.0516     0.0768
    12    4.0090    30.7600    -0.1475     -0.0540     0.0843
    13    5.0270    30.8700    -0.1829     -0.0569     0.0945
    14    6.0170    30.9700    -0.2232     -0.0573     0.1055
    15    7.0080    30.7800    -0.2520     -0.0639     0.1252
    16    8.0220    30.7500    -0.2893     -0.0808     0.1600
    17    9.0120    30.6200    -0.3134     -0.1083     0.2096
    18   10.0200    30.5800    -0.3399     -0.1531     0.2906
    19   11.0200    30.5500    -0.3563     -0.2017     0.3754
    20   12.0200    30.5700    -0.3670     -0.2554     0.4665
    21   13.0100    30.1200    -0.3631     -0.3036     0.5426
    22   14.0100    30.4500    -0.3683     -0.3531     0.6267
    23    6.0170    30.5400    -0.2189     -0.0563     0.1059
    24    4.0100    30.9000    -0.1449     -0.0522     0.0851
    25    2.0050    30.4000    -0.0647     -0.0458     0.0726
    26    0.0122    30.7500     0.0052     -0.0335     0.0619
    27   -1.9620    30.7300     0.0821     -0.0144     0.0513
    28   -3.9790    30.3600     0.1579      0.0044     0.0436
    29    0.0122     0.2240     0.0038      0.0054     0.0014
RUN # 52702   DATA IS STORED IN FILE# 9
```

# TABLE XXXVI

```
RUN 052701    ON 27 MAY 1977
PLATE PLUS FAIRING AND WING
NOMINAL Q= 20 PSF


@
> SCAN

 #      CH. 0      CH. 1      CH. 2      CH. 3      CH. 4

030     .0122      .1477      .0041      .0038      .0024
031     .0123      20.24      .0118     -.0198      .0430
032    -5.961      20.21      .1608      .0324      .0246
033    -4.963      20.04      .1348      .0211      .0251
034    -3.967      19.91      .1118      .0129      .0252
035    -2.956      19.63      .0833      .0031      .0285
036    -1.961      20.04      .0585     -.0024      .0315
037    -.9538      19.91      .0354     -.0115      .0367
038     .0122      20.10      .0089     -.0205      .0422
039     1.015      19.88     -.0149     -.0286      .0465
040     2.002      20.13     -.0407     -.0342      .0519
041     3.021      20.07     -.0651     -.0389      .0584
042     4.009      20.15     -.0857     -.0442      .0655
043     5.025      20.02     -.1150     -.0461      .0713
044     6.017      20.20     -.1395     -.0503      .0810
045     7.032      19.97     -.1621     -.0550      .0927
046     8.021      20.15     -.1814     -.0675      .1160
047     9.012      20.05     -.2031     -.0906      .1575
048     10.01      19.72     -.2152     -.1229      .2103
049     11.02      19.92     -.2296     -.1559      .2678
050     12.02      19.74     -.2334     -.1913      .3256
051     13.01      19.83     -.2365     -.2282      .3848
052     14.01      19.63     -.2323     -.2573      .4277
053     6.017      20.03     -.1401     -.0477      .0787
054     4.010      20.31     -.0886     -.0422      .0654
055     2.002      19.82     -.0391     -.0323      .0509
056     .0122      20.30      .0068     -.0197      .0425
057    -1.961      20.10      .0669     -.0005      .0301
058    -3.979      19.93      .1154      .0138      .0230
059     .0122      20.08      .0103     -.0200      .0431
060     .0122      .1900      .0043      .0048      .0022
```

## TABLE XXXVII

```
RUN NO:   52701

ROW #      CH0          CH1          CH2          CH3          CH4
    1    0.0122       0.1477       0.0041       0.0038      0.0024
    2   -5.9610      20.2100       0.1608       0.0324      0.0246
    3   -4.9630      20.0400       0.1348       0.0211      0.0251
    4   -3.9670      19.9100       0.1118       0.0129      0.0252
    5   -2.9560      19.6300       0.0833       0.0031      0.0285
    6   -1.9610      20.0400       0.0585      -0.0024      0.0315
    7   -0.9538      19.9100       0.0354      -0.0115      0.0367
    8    0.0122      20.1000       0.0089      -0.0205      0.0422
    9    1.0150      19.9800      -0.0149      -0.0286      0.0465
   10    2.0020      20.1300      -0.0407      -0.0342      0.0519
   11    3.0210      20.0700      -0.0651      -0.0389      0.0584
   12    4.0090      20.1500      -0.0857      -0.0442      0.0655
   13    5.0250      20.0200      -0.1150      -0.0461      0.0713
   14    6.0170      20.2000      -0.1395      -0.0503      0.0810
   15    7.0320      19.9700      -0.1621      -0.0550      0.0927
   16    8.0210      20.1500      -0.1814      -0.0675      0.1160
   17    9.0120      20.0500      -0.2031      -0.0906      0.1575
   18   10.0100      19.7200      -0.2152      -0.1229      0.2103
   19   11.0200      19.9200      -0.2296      -0.1559      0.2678
   20   12.0200      19.7400      -0.2334      -0.1913      0.3256
   21   13.0100      19.8300      -0.2365      -0.2282      0.3848
   22   14.0100      19.6300      -0.2323      -0.2573      0.4277
   23    6.0170      20.6300      -0.1401      -0.0477      0.0787
   24    4.0100      20.3100      -0.0886      -0.0422      0.0654
   25    2.0020      19.8200      -0.0391      -0.0323      0.0509
   26    0.0122      20.3000       0.0068      -0.0197      0.0425
   27   -1.9610      20.1000       0.0669      -0.0005      0.0301
   28   -3.9790      19.9300       0.1154       0.0138      0.0230
   29    0.0122       0.1900       0.0043       0.0048      0.0022
RUN # 52701    DATA IS STORED IN FILE# 8
```

# TABLE XXXVIII

```
WEIGHT TARE...PLATE PLUS FAIRING AND WING
27 MAY 1977 AT 1620

W@
> SCAN

#     CH. 0     CH. 1     CH. 2     CH. 3     CH. 4

001    .0124    .1410    .0036    .0025    .0038
002   -5.949    .1404    .0038    .0408   -.0182
003   -4.959    .1383    .0033    .0346   -.0140
004   -3.943    .1418    .0035    .0278   -.0099
005   -2.951    .1419    .0033    .0212   -.0056
006   -1.961    .1438    .0047    .0160    .0006
007   -.9545    .1456    .0042    .0102    .0012
008    .0122    .1435    .0049    .0038    .0039
009    1.016    .1436    .0052    .0012    .0062
010    2.003    .1457    .0047   -.0043    .0111
011    3.022    .1456    .0046   -.0103    .0165
012    4.010    .1467    .0045   -.0171    .0208
013    4.996    .1446    .0046   -.0228    .0245
014    6.017    .1411    .0041   -.0287    .0285
015    7.008    .1443    .0039   -.0352    .0316
016    8.022    .1433    .0045   -.0402    .0364
017    9.028    .1434    .0040   -.0464    .0391
018    10.03    .1456    .0044   -.0517    .0436
019    11.02    .1476    .0042   -.0574    .0476
020    12.01    .1492    .0046   -.0627    .0516
021    13.00    .1485    .0042   -.0682    .0540
022    14.01    .1496    .0044   -.0736    .0578
023    6.017    .1483    .0041   -.0281    .0281
024    4.009    .1484    .0053   -.0166    .0205
025    2.002    .1501    .0045   -.0035    .0111
026    .0122    .1488    .0057    .0045    .0015
027   -1.960    .1543    .0055    .0165   -.0012
028   -3.977    .1552    .0048    .0298   -.0108
029    .0122    .1497    .0050    .0045    .0024
```

## TABLE XXXIX

```
RUN NO:   52777

ROW #      CH0          CH1          CH2          CH3          CH4
    1    0.0124       0.1410       0.0036       0.0025       0.0038
    2   -5.9490       0.1404       0.0038       0.0408      -0.0182
    3   -4.9590       0.1383       0.0033       0.0346      -0.0140
    4   -3.9430       0.1418       0.0035       0.0278      -0.0099
    5   -2.9510       0.1419       0.0033       0.0212      -0.0056
    6   -1.9610       0.1438       0.0047       0.0160       0.0006
    7   -0.9545       0.1456       0.0042       0.0102       0.0012
    8    0.0122       0.1435       0.0049       0.0038       0.0039
    9    1.0160       0.1436       0.0052       0.0012       0.0062
   10    2.0030       0.1457       0.0047      -0.0043       0.0111
   11    3.0220       0.1456       0.0046      -0.0103       0.0165
   12    4.0100       0.1467       0.0045      -0.0171       0.0208
   13    4.9960       0.1446       0.0046      -0.0228       0.0245
   14    6.0170       0.1411       0.0041      -0.0287       0.0285
   15    7.0080       0.1443       0.0039      -0.0352       0.0316
   16    8.0220       0.1433       0.0045      -0.0402       0.0364
   17    9.0280       0.1434       0.0040      -0.0464       0.0391
   18   10.0300       0.1456       0.0044      -0.0517       0.0436
   19   11.0200       0.1476       0.0042      -0.0574       0.0476
   20   12.0100       0.1492       0.0046      -0.0627       0.0516
   21   13.0000       0.1485       0.0042      -0.0682       0.0540
   22   14.0100       0.1496       0.0044      -0.0736       0.0578
   23    6.0170       0.1483       0.0041      -0.0281       0.0281
   24    4.0090       0.1484       0.0053      -0.0166       0.0205
   25    2.0020       0.1501       0.0045      -0.0035       0.0111
   26    0.0122       0.1488       0.0057       0.0045       0.0015
   27   -1.9600       0.1543       0.0055       0.0165      -0.0012
   28   -3.9770       0.1552       0.0048       0.0298      -0.0108
   29    0.0122       0.1497       0.0050       0.0045       0.0024
 RUN # 52777   DATA IS STORED IN FILE# 7
```

## COMPUTER PROGRAMS

### Program A

```
10 COM R1,D[40,5]
11 REM.......
12 REM "TUNNEL DATA PROCESSING"
13 REM "PROGRAM TO STORE DATA ON TAPE"
14 REM ......
20 DISP "ENTER RUN #";
30 INPUT R1
40 DISP "ENTER # OF DATA ROWS";
50 INPUT J
60 FOR N=1 TO J
70 DISP "ENTER DATA ROW";N;"";
80 INPUT D[N,1],D[N,2],D[N,3],D[N,4],D[N,5]
90 NEXT N
91 PRINT
92 PRINT "RUN NO: "R1
93 PRINT
95 PRINT "ROW #"TAB10"CH0"TAB20"CH1"TAB30"CH2"TAB40"CH3"TAB50"CH4"
100 FOR N=1 TO J
110 WRITE (15,300)N,D[N,1],D[N,2],D[N,3],D[N,4],D[N,5]
115 NEXT N
120 DISP "VERIFY DATA, PRESS (CONT-EXEC) ";
125 STOP
130 DISP "INPUT STORAGE FILE #";
140 INPUT Z
150 STORE  DATA Z
155 PRINT "RUN #"R1"DATA IS STORED IN FILE#"Z""
300 FORMAT 2X,F3.0,2X,F7.4,3X,F7.4,3X,F7.4,3X,F7.4,3X,F7.4
500 END
```

Program B

```
1 COM R1,D[40,5]
10 REM .....
11 REM "TUNNEL DATA PROCESSING"
12 REM "PROGRAM TO GENERATE CL,CD,CM-C/4 FOR 3 STRUT MOUNT"
13 REM .....
20 DIM A[3,3],L[3,1],X[40,5],T[40,5],C[40,5],U$[80],Y[3,1],V[40,5],W[40,5]
30 MAT READ A
40 DATA -96.154,0,0,0,17.5,25.575,0,-85.065,-65.07
50 C1=0.5
60 S1=1.5
61 DISP "ENTER # OF DATA ROWS";
62 INPUT J
70 DISP "ENTER WIND OFF WT TARE FILE #";
80 INPUT G
90 LOAD  DATA G
120 K1=(D[1,3]+D[J,3])/2
130 K2=(D[1,4]+D[J,4])/2
140 K3=(D[1,5]+D[J,5])/2
150 FOR N=2 TO J-1
160 FOR K=1 TO 2
170 T[N-1,K]=D[N,K]
180 NEXT K
190 T[N-1,3]=D[N,3]-K1
200 T[N-1,4]=D[N,4]-K2
210 T[N-1,5]=D[N,5]-K3
220 NEXT N
237 DISP "ENTER Q CAL FOR RUN";
238 INPUT Z
239 DISP "ENTER RUN FILE #";
240 INPUT G
250 LOAD  DATA G
```

```
260 K1=(D[1,2]+D[J,2])/2
270 K2=(D[1,3]+D[J,3])/2
280 K3=(D[1,4]+D[J,4])/2
290 K4=(D[1,5]+D[J,5])/2
300 FOR N=2 TO J-1
310 X[N-1,1]=D[N,1]
320 X[N-1,2]=(D[N,2]-K1)*2/0.1084
330 X[N-1,3]=D[N,3]-K2
340 X[N-1,4]=D[N,4]-K3
350 X[N-1,5]=D[N,5]-K4
360 NEXT N
370 FOR N=1 TO J-2
380 L[1,1]=X[N,3]-T[N,3]
390 L[2,1]=X[N,4]-T[N,4]
400 L[3,1]=X[N,5]-T[N,5]
410 MAT Y=A*L
420 X[N,3]=Y[1,1]/(X[N,2]*S1)
430 X[N,4]=Y[2,1]/(X[N,2]*S1)
440 X[N,5]=Y[3,1]/(X[N,2]*S1*C1)
450 NEXT N
870 PRINT "CORRECTED DATA OF RUN #"R1
880 DISP "INPUT WALL CORR'N-DRAG";
890 INPUT B
900 DISP "ENTER WALL CORR'N-AOA";
910 INPUT F
920 FOR N=1 TO J-2
930 A1=X[N,1]/57.3
940 D[N,3]=X[N,3]
950 D[N,4]=X[N,4]+B*D[N,3]↑2
960 D[N,5]=X[N,5]+(D[N,3]*0.008333*SIN(A1)-D[N,4]*0.008333*COS(A1))/C1
970 D[N,1]=X[N,1]+F*D[N,3]
980 D[N,2]=X[N,2]
990 NEXT N
```

```
1000 PRINT "ROW #"TAB8"AOA(DEG)"TAB18"Q(PSF)"TAB30"CL"TAB40"CD"TAB48"CM-C/4"
1010 FOR N=1 TO J-2
1020 WRITE (15,1300)N,D[N,1],D[N,2],D[N,3],D[N,4],D[N,5]
1030 NEXT N
1040 DISP "CHECK DATA,PRESS (CONT-EXEC)";
1050 STOP
1060 DISP "ENTER FILE # FOR REDUCED DATA";
1070 INPUT Z
1080 STORE  DATA Z
1090 PRINT "RUN #"R1"REDUCED DATA IS STORED IN FILE #"Z" "
1300 FORMAT 2X,F3.0,1X,F8.4,2X,F8.4,3X,F7.4,3X,F7.4,3X,F7.4
1400 GOTO 237
1410 END
```

Program C

```
1 COM K1,D[40,5]
10 REM .....
11 REM "TUNNEL DATA PROCESSING"
12 REM "PROGRAM TO GENERATE CL,CD,CM-C/4"
13 REM .....
20 DIM A[3,3],L[3,1],X[40,5],T[40,5],C[40,5],U$[80],Y[3,1],V[40,5],W[40,5]
30 MAT READ A
40 DATA -96.154,0,0,0,17.5,25.575,0,-89.065,-66.07
50 C1=0.5
60 S1=1.5
61 DISP "ENTER # OF DATA ROWS";
62 INPUT J
70 DISP "ENTER WD/WG OFF THRE DATA FILE #";
80 INPUT G
90 LOAD  DATA G
120 K1=(D[1,3]+D[J,3])/2
130 K2=(D[1,4]+D[J,4])/2
140 K3=(D[1,5]+D[J,5])/2
150 FOR N=2 TO J-1
160 FOR K=1 TO 2
170 T[N-1,K]=D[N,K]
180 NEXT K
190 T[N-1,3]=D[N,3]-K1
200 T[N-1,4]=D[N,4]-K2
210 T[N-1,5]=D[N,5]-K3
220 NEXT N
221 DISP "ENTER WD OFF/WG ON TARE FILE #";
222 INPUT G
223 LOAD  DATA G
224 K1=(D[1,3]+D[J,3])/2
225 K2=(D[1,4]+D[J,4])/2
226 K3=(D[1,5]+D[J,5])/2
```

```
227 FOR N=2 TO J-1
228 FOR K=1 TO 2
229 V[N-1,K]=D[N,K]
230 NEXT K
231 V[N-1,3]=D[N,3]-K1
232 V[N-1,4]=D[N,4]-K2
233 V[N-1,5]=D[N,5]-K3
234 NEXT N
237 DISP "ENTER Q CAL OF 05-25-77 FOR RUN";
238 INPUT Z
239 DISP "ENTER WING OFF RUN FILE #";
240 INPUT G
250 LOAD  DATA G
260 K1=(D[1,2]+D[J,2])/2
270 K2=(D[1,3]+D[J,3])/2
280 K3=(D[1,4]+D[J,4])/2
290 K4=(D[1,5]+D[J,5])/2
300 FOR N=2 TO J-1
310 X[N-1,1]=D[N,1]
320 X[N-1,2]=(D[N,2]-K1)*Z/0.1084
330 X[N-1,3]=D[N,3]-K2
340 X[N-1,4]=D[N,4]-K3
350 X[N-1,5]=D[N,5]-K4
360 NEXT N
370 FOR N=1 TO J-2
380 L[1,1]=X[N,3]-T[N,3]
390 L[2,1]=X[N,4]-T[N,4]
400 L[3,1]=X[N,5]-T[N,5]
410 MAT Y=A*L
420 X[N,3]=Y[1,1]/(X[N,2]*S1)
430 X[N,4]=Y[2,1]/(X[N,2]*S1)
440 X[N,5]=Y[3,1]/(X[N,2]*S1*C1)
450 NEXT N
```

```
640 DISP "ENTER WING ON RUN FILE #";
650 INPUT G
660 LOAD  DATA G
670 K1=(D[1,2]+D[J,2])/2
680 K2=(D[1,3]+D[J,3])/2
690 K3=(D[1,4]+D[J,4])/2
700 K4=(D[1,5]+D[J,5])/2
710 FOR N=2 TO J-1
720 C[N-1,1]=D[N,1]
730 C[N-1,2]=(D[N,2]-K1)*Z
740 C[N-1,3]=D[N,3]-K2
750 C[N-1,4]=D[N,4]-K3
760 C[N-1,5]=D[N,5]-K4
770 NEXT N
780 FOR N=1 TO J-2
790 L[1,1]=C[N,3]-V[N,3]
800 L[2,1]=C[N,4]-V[N,4]
810 L[3,1]=C[N,5]-V[N,5]
820 MAT Y=A*L
830 C[N,3]=Y[1,1]/(C[N,2]*S1)
840 C[N,4]=Y[2,1]/(C[N,2]*S1)
850 C[N,5]=Y[3,1]/(C[N,2]*S1*C1)
860 NEXT N
870 PRINT "CORRECTED DATA OF RUN #"R1
880 DISP "INPUT WALL CORR'N-DRAG";
890 INPUT B
900 DISP "ENTER WALL CORR'N-AOA";
910 INPUT F
911 DISP "ENTER HEIGHT ABOVE TRUNNION (FT)";
912 INPUT H
```

```
920 FOR N=1 TO J-2
930 A1=C[N,1]/57.3
940 D[N,3]=C[N,3]-X[N,3]
950 D[N,4]=(C[N,4]-X[N,4])+B*D[N,3]↑2
960 D[N,5]=(C[N,5]-X[N,5])+(D[N,3]*H*SIN(A1)+D[N,4]*(1.166-H*COS(A1)))/C1
970 D[N,1]=C[N,1]+F*D[N,3]
980 D[N,2]=C[N,2]
990 NEXT N
1000 PRINT "ROW #"TAB8"AOA(DEG)"TAB18"Q(PSF)'TAB30"CL"TAB40"CD"TAB48"CM-C/4"
1010 FOR N=1 TO J-2
1020 WRITE (15,1300)N;D[N,1],D[N,2],D[N,3],D[N,4],D[N,5]
1030 NEXT N
1040 DISP "CHECK DATA,PRESS (CONT-EXEC)";
1050 STOP
1060 DISP "ENTER FILE # FOR REDUCED DATA';
1070 INPUT Z
1080 STORE  DATA Z
1090 PRINT "RUN #"R1"REDUCED DATA IS STORED IN FILE #"Z" "
1300 FORMAT 2X,F3.0,1X,F8.4,2X,F8.4,3X,F7.4,3X,F7.4,3X,F7.4
1400 GOTO 237
1410 END
```

## PROGRAM C(a)

## MODIFICATION TO COMPUTE AERODYNAMIC TARES

```
870 PRINT "AERODYNAMIC TARES OF RUN #"R1
880 DISP "INPUT WALL CORR'N-DRAG";
890 INPUT B
900 DISP "ENTER WALL CORR'N-AOA";
910 INPUT F
911 DISP "ENTER HEIGHT ABOVE TRUNNION (FT)";
912 INPUT H
920 FOR N=1 TO J-2
930 A1=C[N,1]/57.3
940 D[N,3]=C[N,3]-X[N,3]
941 W[N,3]=-X[N,3]
950 D[N,4]=(C[N,4]-X[N,4])+B*D[N,3]↑2
951 W[N,4]=-X[N,4]
960 D[N,5]=(C[N,5]-X[N,5])+(D[N,3]*H*SIN(A1)+D[N,4]*(1.166-H*COS(A1)))/C1
961 W[N,5]=-X[N,5]
970 D[N,1]=C[N,1]+F*D[N,3]
980 D[N,2]=C[N,2]
990 NEXT N
1000 PRINT "ROW #"TAB8"AOA(DEG)"TAB18"Q(PSF)"TAB29"DCL"TAB39"DCD"TAB47"DCM-C/4"
1010 FOR N=1 TO J-2
1020 WRITE (15,1300)N,D[N,1],D[N,2],W[N,3],W[N,4],W[N,5]
1030 NEXT N
1040 DISP "CHECK DATA,PRESS (CONT-EXEC)";
1050 STOP
1060 DISP "ENTER FILE # FOR REDUCED DATA";
1070 INPUT Z
1080 STORE  DATA Z
1090 PRINT "RUN #"R1"REDUCED AERO TARES ARE STORED IN FILE #"Z" "
1300 FORMAT 2X,F3.0,1X,F8.4,2X,F8.4,3X,F7.4,3X,F7.4,3X,F7.4
1400 GOTO 237
1410 END
```

# REFERENCES

1. Concannon, M. J., Design Study of a Strain Gauge Wind Tunnel Balance, M.S. Thesis, Naval Postgraduate School, Monterey, March 1974.

2. Casko, J. D., A Microprocessor Controlled Automatic Data Logging System - (ADL), M. S. Thesis, Naval Postgraduate School, Monterey, June 1977.

3. Heard, C. A., Wind Tunnel Wall Corrections for Arbitrary Planforms and Wind Tunnel Cross-sections, M.S. Thesis, Naval Postgraduate School, Monterey, June 1977.

4. Pope, A. and Harper, J. J., Low-speed Wind Tunnel Testing, Wiley, 1966.

5. Dommasch, D. O., Sherby, S. S., and Connolly, T. F., Airplane Aerodynamics, Pitman, 1967. Pg. 49-53.

6. Abbott, I. H. and vonDoenoff, A. E., Theory of Wing Sections, McGraw-Hill, 1949. Pg. 336, 510.

7. Etkin, B., Dynamics of Flight Stability and Control, Wiley, 1959. Pg. 448.

# INITIAL DISTRIBUTION LIST

| | | No. Copies |
|---|---|---|
| 1. | Defense Documentation Center<br>Cameron Station<br>Alexandria, VA 22314 | 2 |
| 2. | Library, Code 0142<br>Naval Postgraduate School<br>Monterey, CA 93940 | 2 |
| 3. | Department Chairman, Code 67<br>Department of Aeronautics<br>Naval Postgraduate School<br>Monterey, CA 93940 | 1 |
| 4. | Professor L. V. Schmidt, Code 67Sx<br>Department of Aeronautics<br>Naval Postgraduate School<br>Monterey, CA 93940 | 1 |
| 5. | LT Robert Wayne Russell, USN<br>1023 Halsey Drive<br>Monterey, CA 93940 | 1 |

The
R9
c.

Thesis
R917
c.1
Russell
171776
Design study of a
centerplate mount for

13 FE
14 MA
14 AP
14 AP
02
04
54
54

Schmidt, Louis E
ID:32768001970148
R917
Design study of a cen
\Russell, Robert Wayne
due:4/27/1997,23:59

Thesis
R917
c.1
Russell
171776
Design study of a
centerplate mount for
wind tunnel models.

thesR917
Design study of a centerplate mount for

3 2768 001 97014 8
DUDLEY KNOX LIBRARY